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AUTHOR Nakagawa, Charles H.; Honquilada, Q. L.
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ABSTRACT

This book provides the basic knowledge and guides for the construction and operation of a small-scale, family-size biogas unit. The first chapter discusses the benefits of biogas production and the Chinese biogas model. The second chapter shows the components, design formulas, and sizing units of the biogas model. Chapter 3 describes actual construction methods. The last chapter outlines the operation and maintenance of the biogas digester. Appendices include: (1) an introduction to the process; (2) design and plan; (3) feasibility study; (4) estimated costs of materials; (5) daily slurry quantities; (6) manure and urine estimates; (7) gas production estimates; (8) masonry; (9) manual tools for construction; (10) formulas and conversions; (11) biogas lamp construction; (12) background for biogas production in the People's Republic of China; and (13) vocabulary. Lists 16 references. (YP)

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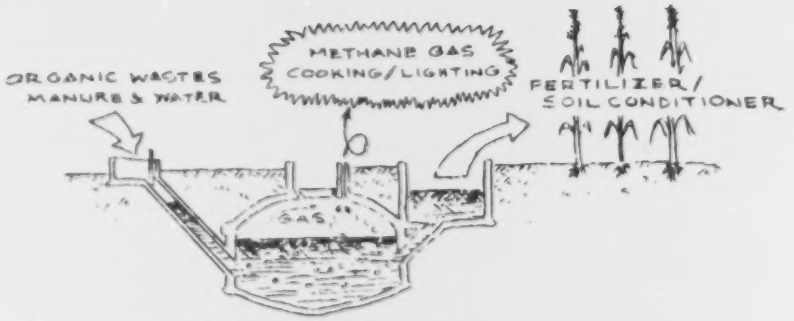

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-CHINESE DESIGN-

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CHINESE BIOGAS DIGESTER

A Potential Model for Small-Scale, Rural Applications
(A Manual for Construction and Operation)

Prepared by:

Charles H. Nakagawa
U.S. Peace Corps Volunteer

with

Q. L. Honquilada

PRRM

A Joint Project of
The Philippine Rural Reconstruction Movement (PRRM)
The U.S. Peace Corps/Philippines
The German Freedom From Hunger/Agro-Action

December 1981

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P R E F A C E

This manual is a result of a two-year project entitled "The Development and Promotion of Biogas Project Under Philippine Conditions", jointly undertaken by the Philippine Rural Reconstruction Movement (PRRM), the US Peace Corps/Philippines, and the German Freedom From Hunger/Agro-Action. In general, the project aims to contribute to the widespread dissemination and actual utilization of biogas technology particularly in the rural villages.

Singling out the Chinese design as the most appropriate type at the moment for small-scale, backyard livestock-raising families is dictated by the following reasons: (a) it is less costly, volume-for-volume, compared with other existing designs; (b) it is more durable and entails less maintenance for it has fewer metal components and moving parts; and (c) it is capable of delivering a higher gas pressure, thus making it possible to utilize the gas for lighting purposes.

The pieces of information in this manual provide the basic knowledge and guides for the construction and operation of a small-scale, family-size Chinese biogas unit as adapted to Philippine rural conditions. These are not original ideas of the writers but gathered and learned from a lot of people and reading materials, as well as from actual experiences in building a number of biogas units. Encouragingly, these units have already been operational.

We owe the following special thanks and acknowledgements: the Chengdu Biogas Research Institute Team - - composed of Dr. Xu Yiz Hong (team leader, and biologist), Dr. Cao Guo Qiang (architect), and Dr. Lo Xing Yun (translator) - - who were at one time with the Central Luzon State University, for painstakingly sharing the basic information, principles and other "secrets" of the Chinese biogas model with one of this manual's writers, Charles Nakagawa; Nestor de Guzman, a local ingenious mason who had made significant useful modifications in the construction of a Chinese biogas digester and which are now incorporated in this manual; and Esther dela Cruz for ably and patiently typing the manuscript.

By and large, this manual is only an initial attempt. Suggestions and comments for its improvement and refinement will be greatly appreciated.

The benefits a family can derive from having a biogas unit cannot be over-emphasized. The unit will not only provide an efficient disposal and treatment system for manure and other organic wastes but

also valuable fuel for cooking and even lighting, as well high quality organic fertilizers. On a larger scale, this means, among other things, environmental sanitation, energy self-reliance and savings on the part of the people.

It is hoped that this manual will, in certain little ways, be helpful to the villagers and development agency personnel in putting the biogas technology into practice.

C. H. N.

Q. L. H.

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1.0 INTRODUCTION

1.1 Why Biogas Production?

Biogas production has received growing attention as a project particularly in the rural areas and among small farmers. Technically, it is a process of converting animal manure and many other organic wastes into fuel and other beneficial uses.

More specifically, biogas production has the following benefits:

1) Direct Benefits to the Farmer:

   a) Methane gas. It is a clean fuel for cooking and lighting, (at the household level), and even running diesel engines. In short, savings in fuel expenses.

   b) Fertilizer. What remains of the manure after gas has been extracted. is high quality organic fertilizer and soil conditioner. Some studies show that it increased crop yield by 10-20% compared to "undigested" ordinarily prepared compost.

   c) Sanitation and Health. Biogas production provides efficient disposal of manure - - controlling smell, water pollution, and access of flies and other disease-carrying pests to the manure. Furthermore, since biogas burns without smoke, irritation to eyes and lungs are prevented.

2) General Benefits to the Country (After biogas production will have become widespread):

   a) Savings in the total economy. It will help conserve foreign exchange through reduced demand for kerosene, gas and commercial fertilizers.

   b) Cleaner environment. This will follow as individual families and enterprises practice an efficient waste disposal system.

   c) Increased possibility for backyard animal raising. With biogas production, animal raising in the homelots can now be undertaken without the usual undesirable smell and other sanitation problems.

   d) Reduced deforestation. In the longrun, biogas would reduce demand for firewood as a primary source of fuel in the rural areas.

CLEANER ENVIRONMENT

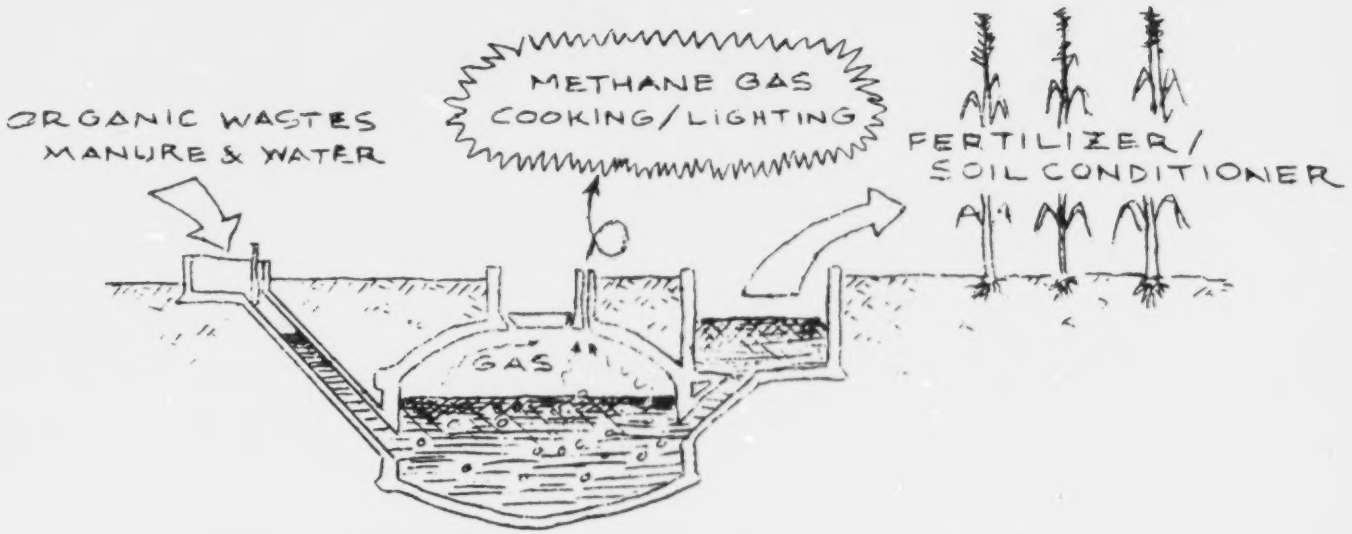


Figure 1: BIOGAS DIGESTER
- CHINESE DESIGN -

1.2 The Chinese Biogas Model: Some Practical Advantages

There are many different biogas models but the Chinese model stands out as a highly promising in the rural areas. It originated from the People's Republic of China where about 7 million units are reported to have been existing. Some of its basic features are:

1) Circular in shape, with a fixed-dome top and saucer-shaped bottom. Being circular, it has the smallest lateral surface area with the pressure and load stresses even distributed, thus compact and solid. Additionally, it is economical in construction materials (up to 20% less than a quadrangle or square structure having the same volume).

2) No moving parts and metal components, except the structural reinforcements. An all concrete structure, hence, it is durable, almost a life-long investment. It is easier to maintain for it has no mechanical moving parts. No welding job is necessary.

3) Completely constructed underground. The digester is therefore insulated from extreme temperature changes. It saves land space for the area above the structure which can be utilized for other purposes like a pig pen. Input materials flow easily into the digester by gravity, thus simplifying operation.

4) Capable of generating higher gas pressure (on the average 10 times higher than floating cover type) is due to an unique gas storage mechanism which does not need a floating tank as other designs do. It uses the displacement principle where slurry moves up and down the specially designed outlet compartment as gas volume changes inside the digester. (See Figure 1 for diagram of the system.)

2.0 BASIC STRUCTURAL FEATURES AND CONSIDERATIONS

2.1 Components

The Chinese biogas model has 8 basic components:

1) Mixing Pit or Inlet. This is where manure and water are measured and mixed before feeding them into the digester. It is equipped with (a) sluice gate usually made of wood to control or allow for the proper mixture of water and manure before the release of the mixture into the digester, and (b) cover - - which can be made of recycled corrugated G.I. sheet.

2) Inlet Pipe. This serves as conveyor of the manure-water mixture or slurry from the mixing pit to the digester. It is a straight slanting pipe, using prefabricated concrete culvert 8 inches minimum inside diameter.

3) Digester/Gas Storage. This is where the slurry is allowed to ferment through bacterial action and where gas is being stored. It is a water and air-tight structure. Some features of the digester are:

a) The flooring of the digester is concave or saucer-type where the inorganic solids and parasite eggs settle and collect.

b) The wall is made of concrete hollowblocks with water-proofing plaster. The inlet/outlet pipes fit midway the wall height.

c) Ringbeam, which acts as the "foundation" of the dome. Made of reinforced concrete; it indicates correct slurry level when the digester is being filled initially.

The gas storage is fixed into the digester. It is that portion above the ringbeam or the space inside the dome. The dome is made of reinforced concrete and is plastered twice and finally sealed with paraffin or wax for complete gas proofing.

4) Outlet Chamber. It serves 2 important functions: (a) where the effluent residue is taken out; and (b) where the slurry is forced out when the gas pressure within digester/gas storage exceeds atmospheric pressure.

The chamber consists of 3 parts:

a) Outlet pit - - is circular in shape, made of concrete hollowblocks with plastering, and having a volume to 1/3 of the volume of the digester/cylinder (V_2).

b) Outlet pipe - - is prefabricated round concrete pipe with 8-inch inside diameter (same as inlet pipe).

c) Cover - - to keep rain water, debris and children from falling into the pit. It can be made of recycled G.I. sheet.

5) Removable Manhole. It provides access to the digester for cleaning, inspection and maintenance. It is made of concrete and is water-sealed. Asphalt material is used for gasket seal.

6) Gas Outlet Pipe. It is located through the manhole sleeve. It is of 1-inch G.I. pipe.

7) Stirrer/Mixer. This is a mechanical devise inside the digester used to stir the fermenting slurry to stimulate gas production and to break the "scum" layer forming at the surface of the slurry. It is fabricated from G.I. pipes and flat bars. (The only component that requires welding.)

8) Backfill. It serves to protect and insulate the concrete dome from the sun (dry and heat) and provides rain water runoff. Soil and gravel with 70% and 30% proportion respectively is recommended.

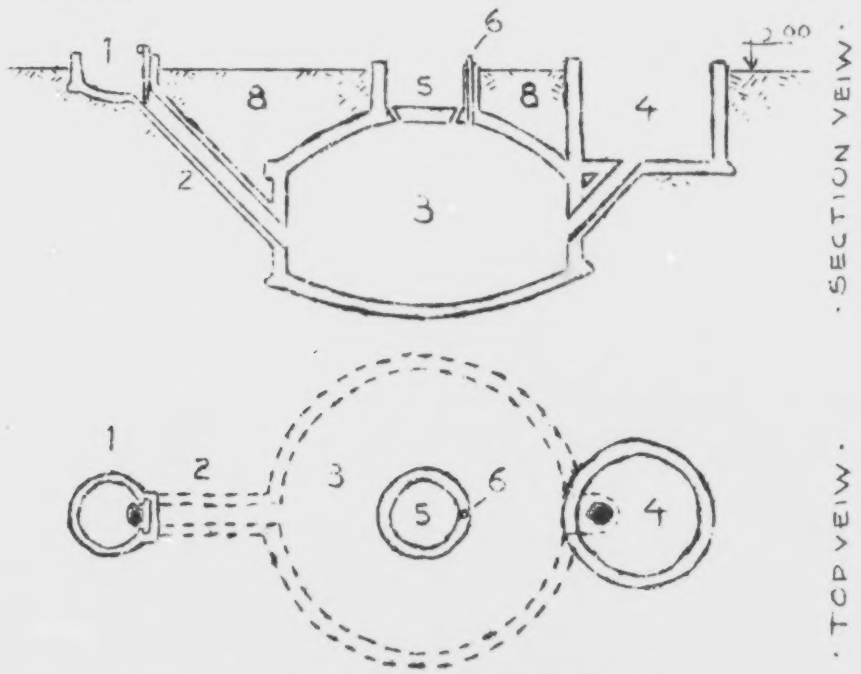


Figure 2: Components of a biogas Unit (stirrer/mixer not shown here)

2.2 Design Formulas

For structural stability and efficient performance, the design of a Chinese Biogas model is governed by certain mathematical formulas 1/ which are as follows:

1) $\frac{h}{d} = \frac{1}{3}$, That is, the diameter of the digester is three times its height.

1/ Source: Chengdu Biogas Research Institute, Sichuan Province, People's Republic of China, June 1980.

2) $\frac{f_1}{d} = \frac{1}{5}$, That is, the distance from the ringbeam to the manhole is one fifth the diameter.

3) $\frac{f_2}{d} = \frac{1}{10}$ That is, the distance from the bottom center to the wall bottom is one-tenth the diameter.

4) $V_{outlet} = 1/3\ V_2$, That is, the volume of outlet chamber, Volume is one-third of the slurry chamber, V_2.

5) $V_{slurry} = V_2 + V_3$, That is, the slurry volume, V_s is equal to volume of the digester below the ring beam.

6) Height of inlet/outlet pipes = 1/2 h, that is, the inlet/outlet pipes are placed one-half the height of the wall.

7) $V_{slurry} = 0.85\ V_t$, That is, the slurry volume is 85% the total digester volume, V_t.

$V_{dome} = 0.15\ V_t$, That is, the gas chamber volume (dome) is 15% of the total digester volume, V_t. This volume relationship allows for gas pressure sufficient enough to force the slurry to the outlet chamber.

8) Mixing pit volume should be slightly larger than the daily charge.

9) Manhole dimensions are standard for all volumes of digesters.

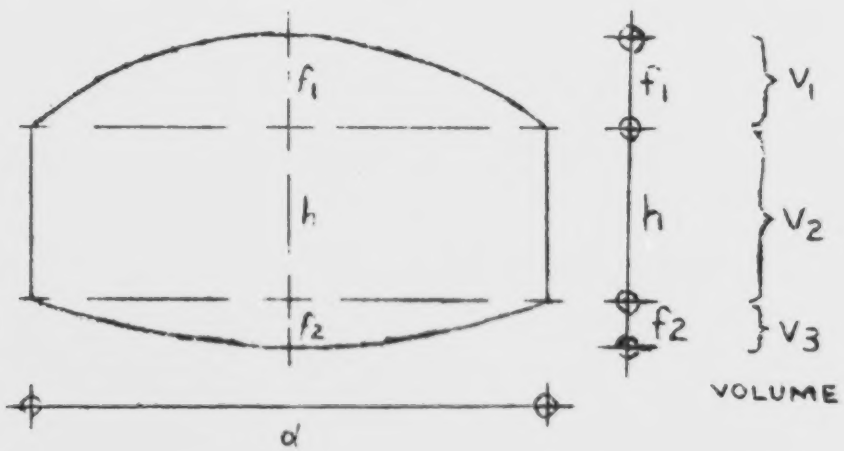


Figure 3: Design Formula

2.3 Sizing Biogas Units

The success of the digester unit depends on the management/operation procedures. A small digester will produce more gas than a large digester with good scientific management. Larger digesters requires more capital costs, more materials and labor. It is often said that it is better to have two smaller digesters rather than one large one.

There are two approaches to sizing a biogas digester. This decision is made by the owner/operator to fit his needs depending upon the situation. These are:

1) The unit to produce a certain amount of gas needed; or,

2) The unit to process/treat a given amount of organic matter (pig manure, carabao manure, night-soil, etc.) as a waste management system, then to see the amount of gas produced, and if that gas produced, and if that gas could be put into good use.

There are cases wherein the volume of organic matter to be treated is large and the need for the gas is minimal. Or the case may be that there is a greater need to treat the waste over the actual gas to be retrieved. The gas need is minimal while there are abundant supplies of organic wastes. Thus, the two approaches in problem solving for the sizing of biogas units are illustrated as follows:

Case A:
1. How much gas do I need daily? (Overriding Consideration)
2. What digester volume is needed to produce this amount of gas?
3. How much daily volume of materials (manure and livestock level) will be required?
4. What is the cost involved? (Feasibility/viability study)

Case B:
1. How much raw materials (manure and other organic wastes) is required to be treated? (Overriding Consideration)
2. What digester volume is needed to handle these materials?
3. What is the amount of gas expected?
4. How will this gas be utilized?
5. What is the cost involved? (Feasibility/viability study)

Following are data and computations needed to answer the different questions:

For Case A:

Question 1. How much gas I need daily?

Gas requirements for appliances:

a) Cooking (medium burner) - 0.28 m^3/hr.

b) Lighting (gas mantle) - 0.14 m^3/hr.

c) Refrigerator (kerosene) 7 ft^3 - 0.20 m^3/hr.

d) Gas engine - 0.56 m^3/Hp/hr.

Calculate how many hours each appliance is used per day and multiply it with the energy consumption.

For example:

- Two stoves (3 hrs./day x 0.28 m^3/hr. x 2 stoves) = 1.68 m^3/day

- One lamp (2 hrs./day x 0.14 m^3/hr.) = 0.28 m^3/day

Total = 1.96 m^3/day

Question 2. What is the digester (slurry) volume to produce this gas per day?

Under average Philippine climatic conditions, estimate gas production at 0.4 m^3 (minimum production) for every 1 m^3 of slurry volume. Thus, for a total daily gas requirement of 1.96 m^3, the unit required must have a digester (slurry) volume of 4.9 m^3.

This is solved by a simple ratio and proportion formula as follows:

$$\frac{0.4\ m^3}{1.0\ m^3} = \frac{1.96\ m^3\ \text{(gas needed)}}{x\ \text{(digester volume)}}$$

Cross multiplying will yield:

$$0.4\ x = 1.0 \times 1.96$$

$$x = \frac{1.0 \times 1.96}{0.4}$$

$$x = 4.9\ m^3\ \text{(digester volume)}$$

Since in the Chinese design the digester and gas storage are integrated in one unit, the total digester volume would be slightly higher. Refer to the design to find the slurry volume to correspond to the desired volume. The 6.14 m^3 design has a slurry volume of 4.68 m^3, which seems to be most appropriate for this case.

Question 3. How much raw materials are needed daily to operate this digester?

Let us assume the normal retention time of 40 days (the period of time one sample of slurry remains in the digester.) Then:

4.68 m^3 ÷ 40 days = 0.117 m^3 (daily slurry volume which is also equal to the mixing pit volume)

0.117 m^3 ÷ 2 (or 1:1 manure - water mixture) = 0.0585 m^3 (volume of manure and water mixture needed daily)

or = 58.5 liters of manure and water needed per day.

- determine the livestock level to provide 58.5 liters (kg.) of manures per day. Is it available?

Question 4. What is the cost of the digester?

This varies from place to place depending on the costs of construction materials and labor. Feasibility/ viability study.

For Case B:

To process or recycle for waste management, a given amount of manure, determine the following:

a) total amount of wastes to be treated;

b) volume of digester needed;

c) amount of gas to be expected from the given digester volume;

d) what can be done with the gas generated;

e) cost of building the biogas unit. Feasibility/viability study.

For example: Let us assume a piggery with 20 fatteners always available, and one 75 kg fattener will give approximately 3.75 liters manure/urine per day.

Then:

20 fatteners x 3.75 liter/day = 75 liters of manure per day

75 liters x 2 (with water mixed) = 150 liters of mixture

150 liters x 40 (retention time) = 6,000 liters

6,000 liters x 0.001 (convertion of liter to m^3) = 6.0 m^3 (slurry) volume

6.0 m^3 x 0.4 (gas production rate = 2.4 m^3 of gas per day.

Digester to be built = 8.66 m^3

Biogas can be produced from a very wide range of vegetable matter and all types of animal manure. When vegetable matter is used it is important that it is to be cut into the smallest possible particles. For a continuous-operating biogas digester, it is recommended to avoid vegetable matter since this may lead to "scum" problems quickly. Recommend to use only animal manure (and very little vegetable matter) for continuous-operating biogas digesters.

In China, they base the size of their digesters on these assumptions: each cubic meter of raw material will produce from 0.15 - 0.3 m^3 of gas per day. The low gas production is mainly due to the lower annual temperature in China. (also no mixing; batch operation). Here in the Philippines, we may expect more gas to be produced from the same given volume of raw materials. Under average Philippine climatic conditions, the gas production rate is based on that each cubic meter of raw material will produce 0.4 - 0.6 m^3 of gas per day. This may be due to higher temperatures, mixing and a continuously operated digester. Usually, the size of household biogas digesters in China is from 6 m^3 to 10 m^3, to compensate for the low gas production rates. Here in the Philippine (tropical climates), the household units may be from 4 m^3 to 8 m^3 due to the expected higher gas production.

3.0 CONSTRUCTION

3.1 General Overview of the Construction Process

There are two main phases for the construction of this masonry-type Chinese bio-digester.

Phase I is basically the structural concrete work of the digester. This begins with the Planning/preparation stage to the final concrete plaster application to the inside of the digester/gas dome. The importance here is that all of the concrete work should be carried out continuously, day to day and to avoid any delays in the concrete work. Ideally, the entire digester should be poured all at one time (monolothic), but the imposibility creates the problem of having to pour sections at a time, which makes it hard to avoid "joints", which should be reduced to a minimum. If the joints are not well made, it provides the chance for cleavages/cracks which may lead to leaks in the digester, either water and/or gas leakages. Thus, this part of the construction phase must be continuous and meticulously handled for the desired results. Timing is important and the planning/preparation of the work to be done fully understood by the builder and any carelessness of attention to the quality of construction will interfere with gas production, durability and require even more work (labor, time and materials) to remedy the defect. Each biogas unit should meet specified technical requirements for it to be water and gas tight for the unit to function properly. (For more basic information on masonry work see Appendix H.)

After all of the main structural concrete work has been completed and the "curing" process of the concrete properly started, the Phase I construction is considered finished. The break between Phase I and Phase II is to allow for the proper curing of the concrete, a period of no less than 2 - 3 weeks. The main Phase II activity of paraffin/wax application must be done after this curing period (2-3 weeks), so that "most" of the water has been allowed to dissapate from the concrete during this process, leaving a dry surface. This is necessary in order for the paraffin/wax application stage since if the concrete surface is wet or moist to which the wax is to be applied, it will not adhere as well and will not be an effective gas-seal layer. (the last concrete plaster layer of the dome area to where the wax is to be applied is a "rough" finish). During this curing period ("break" between Phases I and II) the other activities of the Phase II may be done; i.e. stirrer/mixer assembly preparation (welding), gas-piping systems (from digester to the stove, manometer, etc.). The only activity that should be done after the 2 - 3 weeks period are the paraffin/wax application, backfill, manhole and finally, loading (testing for water and gas tightness). Also, during the Phase I period, inspection for any structural damages, check for water and gas tightness will be done before the actual loading of the digester. The basic outline/sequence of events and the process and procedures will be discussed and explained step-by-step so that the builder will have an idea of what should be prepared and required for the specific work.

There are many variations to the construction materials and procedures depending on the availability of building materials in the area. This is how the Chinese are able to build such inexpensive biogas digesters. In this manual we have used a "model" that can be built almost anywhere here in the Philippines, since all of the building materials presented are commonly available at most hardware supply stores, and with which most people are familiar. But by no means is this the only way to construct a Chinese biogas digester and that the builder is not limited to the construction materials specified here. Once the concepts are understood, techniques will be mastered. And having built a few with success, there is plenty of room for improvisation and experimentation, especially in the building materials used - - to lower the cost of construction. The materials presented here are not the lowest possible available, but it is quite inexpensive compared to the "floating" gas-storage type of biogas digester designs on a volume to volume basis. These materials were selected since they were the most commonly available (at local hardware supply stores), not on the merit that they are the most inexpensive available. It is recommended that the builder build at least one of this type presented here in this manual to familiarize himself with design dimensions, techniques and procedures involved. The design and dimensions of the units itself should not be changed from one digester to another of the same volume. Again, there is room for experimentation (try on a small scale first for "new" ideas before applying them on full scale). The method described in this manual has had success in our experience, in terms of materials and methods which were commonly/locally available. Whatever method used, remember that the structure must be solid, firm, water- and gas-tight and durable.

3.2 Phase I

3.2.1 Planning/Preparation

It is recommended that the builder read through the entire construction procedures to have an idea of what is involved, the time period required, and construction materials used.

Here are important reminders in planning for the construction of a biogas unit:

1) Order and purchase all materials preferably in advance. It would be necessary to insure that all materials and tools will be available when needed. Prepare all tools. Have workers inform you if they are low on supplies or check the supplies yourself. Avoid delays in construction.

2) Building a biogas tank is not like building a house or a piggery structure. One crack in a house or piggery structure is permissible but not in a biogas digester. Any source of leak for gas will render the biogas structure useless. Meticulous construction work is stressed for obtaining desired results.

3) Water-proofing concrete is relatively easy, but gas-proofing it is difficult. This requires new skills and materials not applied in ordinary masonry work. Again, meticulous approach to construction and avoid carelessness in work.

4) Costing. Ask the question whether some materials could be suitability substituted by others which are less expensive but adequate enough for the job.

5) Available labor. Check if the required labor and technical skills are easily obtainable and, if not, where to secure them. Also check if some self-help labor is available for this will reduce costs.

6) Check water table. Consider the highest level the water table could rise. In no case should the groundwater level exceed half of the height of the digester wall. Checking water table height involves digging a hole equal to the total depth of the digester during the wettest season of the year. Check the water level in the hole. If necessary, the whole structure may be elevated to compensate for a high water table (although it will involve some problems like more backfill needed, more efforts is lifting/ hauling manure in charging the digester.) As a rule, it is best to avoid high groundwater areas for biogas units.

7) Avoid construction during rainy season. High water table and occasional rains can cause delays in construction which in turn affect the quality of concrete work.

8) Follow strictly scientific methods of working with concrete. The payoff is high - - a durable, more lasting and efficiently functioning biogas unit. Equally important, follow the structural design requirements and specifications.

9) Other reminders. Consider the availability of building materials and skills, cost of materials, available animal wastes, type of soil, knowledge and experience of the builder, and amount of gas required vis-a-vis amount of manure available.

3.3.2 Site Consideration

The location of a biogas unit is a crucial factor to its success as well as to other environmental sanitation requirements. The following are helpful guidelines for choosing an ideal site for the project:

1) Biogas units should be at a site where water table is low. The maximum that water table may be allowed to rise is 1/2 of the height of the digester. If water table of a tentatively selected site is too high, look for another site.

2) It should be located as much as possible downhill or downstream with respect to a well or any water source. Ideally the minimum distance between a biogas unit and a well should be 15-20 meters to avoid water contamination in cases of leaks in the digester.

3) Should be not far from the house or the point of gas utilization to save gas piping cost, but at the same time close as possible to the source of raw materials such as piggery or toilet. This is also to save transport labor and thus guarantee normal gas production.

4) Should be where there is suitable soil and foundation conditions.

5) Should be away from big roots of trees that may damage the structure.

6) Since the biogas unit is completely underground it could be placed either (a) near the house, but in an open area which is exposed to sunlight and therefore heat, for greater gas production; or (b) underneath the house/kitchen or under the animal stalls (which arrangement is common in cold places to protect the digester from extremely low temperature).

In China, the popular arrangement for siting of household biogas units is referred to as "three-in-one" whereby the digester is connected with the piggery and the latrine. The "two-in-one" arrangement is common where either the latrine or the animal pen is attached to the digester.

7) Raw materials (manure, urine, wash water) should be able to "automatically" fed via sloped canals or troughs by the force of gravity to the mixing pit/inlet. This is advisable for increased efficiency and lesser labor cost of hauling and/or lifting the manure.

8) The site should be close to where the effluent is to be used or stored like a vegetable garden or a compost pit.

3.2.3 Excavation

Depending on the soil type, excavation may take 2-3 days. Accurate excavation is important. A poorly dug pit may be a major source of wall/floor settling, and therefore a waste of effort and materials.

Accurate layout of the complete biogas unit is a crucial starting point: from the piggery or source of raw materials to the digester and finally the outlet pit or effluent use.

In planning for excavation, thoroughly investigate the sizing, design, physical layout, materials and tools needed, and construction procedures. These should be discussed jointly by the owners and builders.

Observation of the soil structure/conditions is equally necessary. See if the foundation is sand, clay or solid. Check for groundwater level. See if large roots are present which may damage the structure, if possible destroy them, or find another suitable site.

Before actual digging begins, decide where the excavated soil will be placed. Most of the soil will later be used for backfilling and contouring the area to avoid flooding near the digester. There should be enough space for the movement of materials to the excavated pit when construction begins.

Try to dig as exactly as possible to specifications. Too large an excavation would mean excessive backfill and extra unnecessary expenses; too small, on the other hand, may need additional digging after concrete work has begun. This is undesirable for impurities might get into the concrete.

It is also advisable to dig the pit with sloping walls. In this way "cave-ins" or collapse at the excavated pit walls can be avoided. See following illustration.

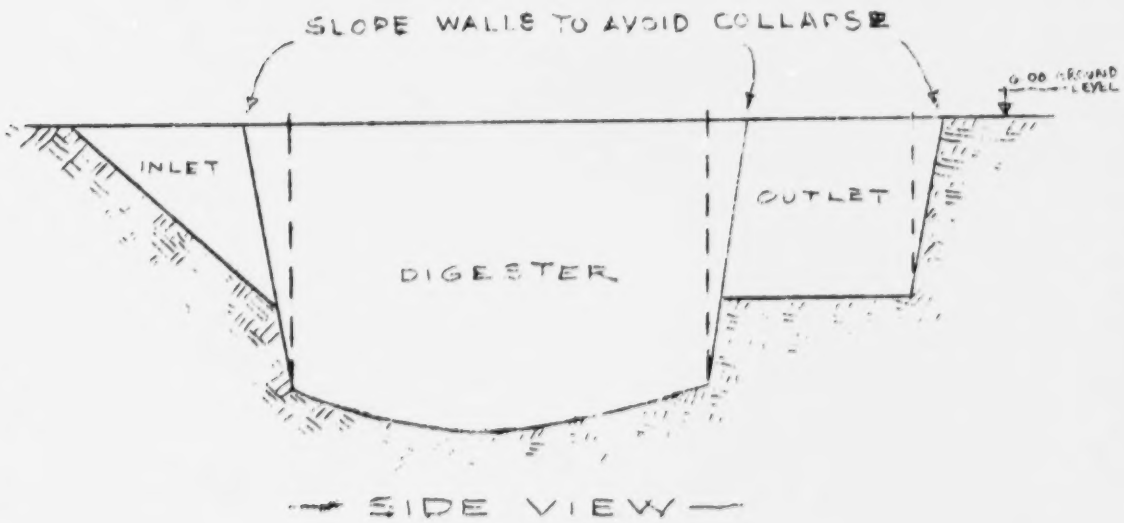


Figure 4: Slope-walled Pit

An allowance of 5-10 centimeters from the outside edge of concrete hollowblock (CHB) wall is sufficient. For example:

- For a 4.66 m^3 digester unit (refer to the design/plan: Appendix B.)

  d = 2.3 m (r = 1.15 m), which is the inside diameter;

  CHB used for walling is 4" x 8" x 16", or 4" thick or 10 cm.

  5-10 cm. allowance for backfill;

Thus,

115 cm. inside radius of digester
+
10 cm. CHB thickness
+
10 cm. backfill allowance
=
135 cm. excavation radius.

In actual digging, first the digester is dug out, then the outlet chamber and finally the inlet pipe groove. (See diagram below.) Note: all excavations should be completed before any concrete work begins.

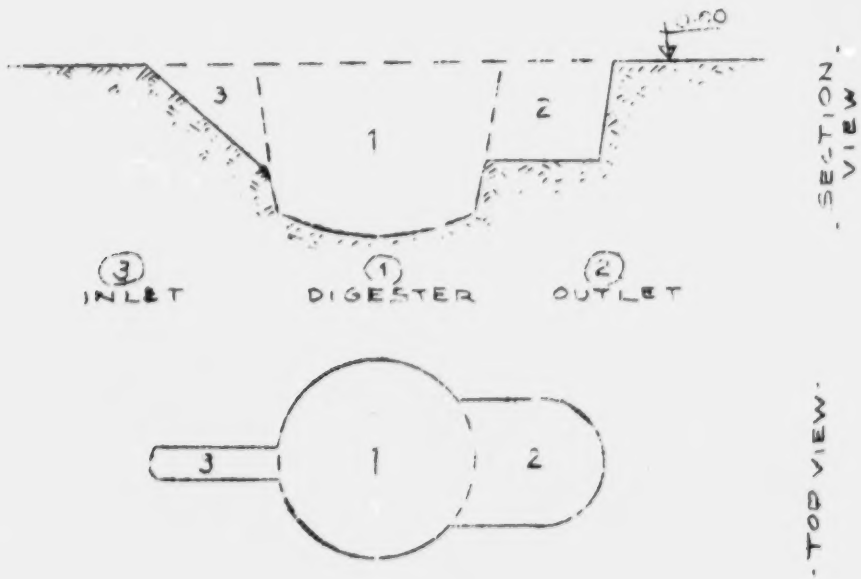


Figure 5:
SEQUENCE OF EXCAVATION.

The excavation procedure is facilitated with the use of a center-pole technique and "f_2" form guide. The center-pole technique is used as a guide for the following:

1) determining the correct radius of the pit;

2) determining the correct curvature for the bottom of the pit (or "f_2" curve/arc);

3) determining the correct thickness of the flooring while concrete is being poured; and

4) laying the CHB_s for the wall construction.

During excavation, at about 10 centimeters before reaching the specified center-depth of the digester, a "center-pole" is placed and fixed securely for the final "touch-up" digging. The procedure involves the following specific steps:

1) A GI pipe (1/2" diameter) is placed vertically at the center of the digester pit. Make sure that it is straight for accurate and also it will later be used for gas piping system.

2) A wooden lumber (2" x 2") spanning across the excavated pit is used to brace the GI pipe. The GI pipe is centered vertically in the pit with the use of a plumb-bob. The 2" x 2" lumber is staked at either ends of the excavated pit and firmly fixed in place.

3) A piece of deformed bar (40 cm. long) is staked at the bottom center of the pit. Through this stake it is advisable to place an end of a tin can so as the GI pipe will not change in position vertically during construction.

4) The GI pipe is placed to the center-stake guide. Check again center accuracy with a plumb-bob. To this GI pipe is attached the "f_2" guide. It is attached in a fashion so that it can rotate on the GI pipe. Appropriate gradations or marking are made on the GI pipe center-pole for guides during construction. The point where the GI pipe is attached to the 2" x 2" lumber is ground level.

(See procedures and drawings below.)

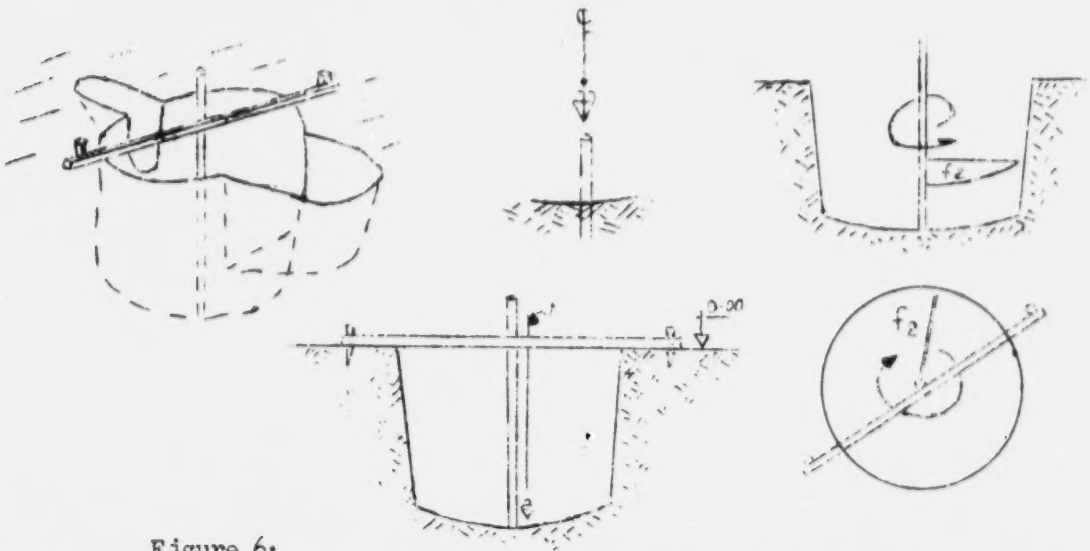


Figure 6:
EXCAVATION. (CENTER POLE TECHNIQUE)

It must be pointed out again that all "fine-touch-up" excavation should be completed before any concrete work is to begin. If not, it is difficult to keep the work area clean and impurities may get into the concrete. The exca ation walls should be "sloped-in". The outlet chamber and inlet pipe groove should also be excavated. Most important, the curvature of the floor should be correct and checked with the use of the "f_2" form guide.

The preparation of the "f_2" form guide for a 4.66 m^3 digester unit takes the following steps:

1) Obtain from the design/plan the dimensions for f_2, d (diameter) and R_2 (radius for f_2, floor curvature/arc). In the case of 4.66 m^3 digester, the dimensions are: f_2 - 0.23 m; d - 2.3 m; R_2 - 2.8 m

2) Prepare tools: tape measure, chalk/pencil, saw, and lawanit or plywood.

3) Mark off the f_2 and the radius of the digester on the lawanit (as shown in the diagram below).

4) Extend tape measure to the R_2 distance (which is 2.8 m). Lay the tape parallel along the f_2 distance and the length of the lawanit (again see diagram).

5) The tape measure will act as a compass. The pivot at the R_2 end of the tape measure and a pencil at the edge of the lawanit of the f_2 mark (at the other end of the tape measure). The end of this f_2 mark and the other mark of the radius of the digester should meet while moving from point "A" to point "B". Draw this curve using this large compass and cut out using the saw.

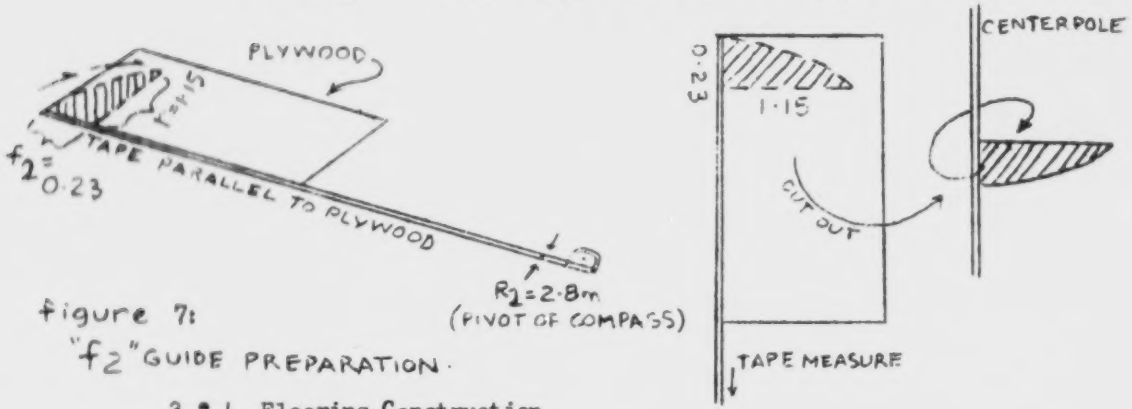


figure 7: "f_2" GUIDE PREPARATION.

3.2.4 Flooring Construction

The concrete flooring will be laid out in two stages. This is so that the work will proceed quickly. The initial flooring section will be on the outer perimeter of the digester to allow for the continuation of the wall construction. If the entire flooring is to be poured all at the same time, there is a danger construction may be delayed since there would be no working space available on the newly laid concrete floor, since it must be cured before anyone is to walk on it.

The flooring should be reinforced concrete, thus there is a need to prepare the steel reinforcement bars. Reinforced concrete will assume the strength of the floor, along with being concave in shape.

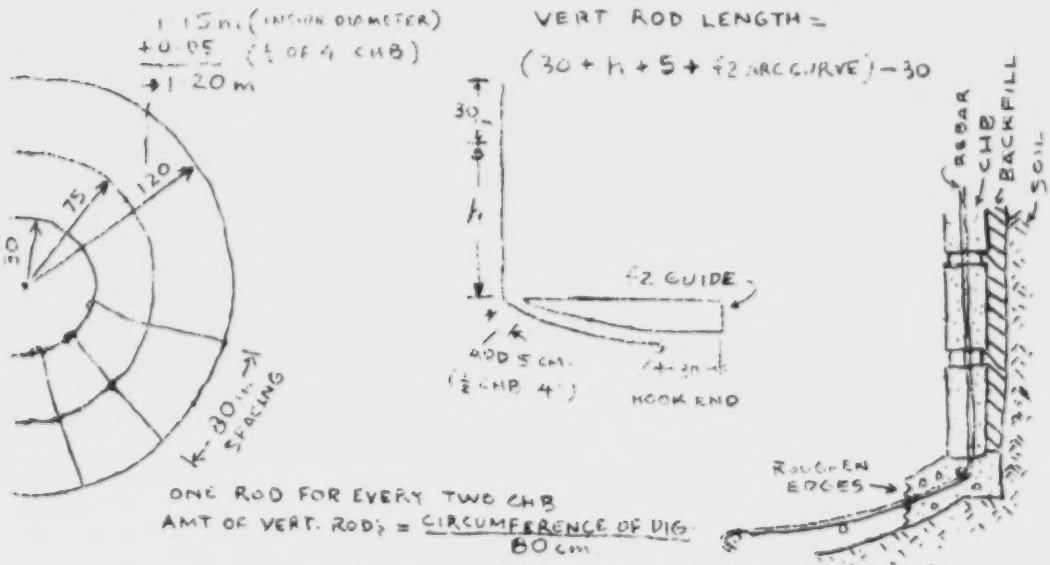
Some guides in preparing the flooring reinforcement steel bars:

1) One vertical bar for every two CHB_s (or every 80 cm.).

2) For a 4.66 m^3 digester unit, three circle bars are necessary. The first, or the smallest, is standard for all digester volumes. This would be the open-center circle about 60 cm. in diameter. The largest circle, placed on the outer perimeter of the digester, is directly on-center under the CHB wall. The second circle would be placed mid-way between the smallest and the largest circles. Note that this is sufficient reinforcement for this volume of digester, there may be a need to add more steel reinforcements for larger digester volumes.

3) Secure and tie all reinforcement bars together with GI wire.

4) Leave the joining edges of the flooring to be completed a rough finish so that the bond between the concrete flooring will be water tight.



FLOORING - STEEL BAR PREPARATIONS.
Figure 8: SPECIFIC EXAMPLE FOR 4.66 m^3 DIGESTER.
(ALL DIMENSIONS ARE IN CM.)

3.2.5 Wall Construction

Wall of the digester is made of CHB_s: 4" x 8" x 16" for digester volumes up to 6 m^3 and 6" x 8" x 16" for larger digester volumes. This CHB will be constructed to form a circular structure.

Wall construction is relatively easy and quick.

The following are important guides/reminders in constructing the wall:

1) There will be working space within the digester since the only portion of the floor that is laid is the area where the CHB is to be placed for the wall.

2) Use the "f_2" form guide for correct radius distance from the center to the CHB and in turn, to achieve a circular structure. Check distance at CHB at centers of the block, both left and right edges would be equidistantly spaced.

3) Although the radius measurement is correct, double check to make sure the center-pole is vertically correct (use "plumb-bob").

4) Fill in mortar only in holes of the CHB with either vertical reinforcing bars or adjoining CHB. All other CHB holes may be left empty so it may act as insulation to increase temperature within the digester (e.g. double-wall insulation concept).

5) Use sufficient mortar when laying CHB_s. Remove all excess mortar.

6) Place horizontal "ring" reinforcement bars for every two CHB height. Secure and tie with GI wire to the vertical reinforcements.

7) Placement of concrete culvert pipes (prefabricated RC pipes) for inlet/outlet is carried out simultaneously with wall construction.

8) Placement of inlet/outlet pipes should be at <u>one-half</u> the height of the wall. Be careful when placing the pipes; they are heavy and laid at a steep angle and the newly installed CHBs are fragile and will move. There may be a need to brace/support to hold the pipes in place (see diagram). The half-way position of the outlet pipe is designed to allow the parasites eggs to settle in the digester and not being easily expelled with the effluent, thus reducing the health hazard.

9) The correct angle with which the pipes are to be positioned is particularly important. Make sure that a line can be made from the outer lip of the outlet chamber to follow the angle of the outlet pipe. This is to make it possible to "purge" and clear the outlet pipe of blockage from time to time. The pipes should be straight so that a long stick or rod (such as a bamboo pole) may pass through for clearing the inlet/outlet pipes. (See diagram below)

10) The pipes should have a minimum of diameter of 8 inches. The larger the pipe the better since clogging will be reduced. The use of ready-made, culvert pipes may be substituted with "make-your-own" pipe with the use of banana stalk larger than 8" in diameter to serve as the inner mold. However, it should be

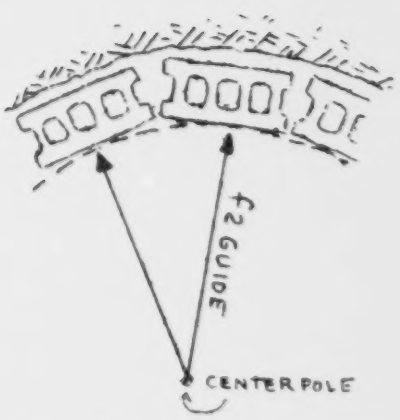
noted that this may consume more cement.

11) Don't move the pipes while the wall construction proceeds.

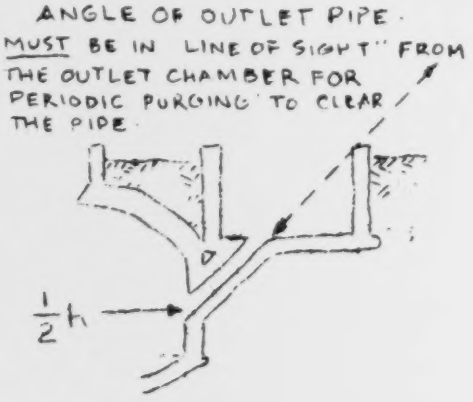
12) Pour sufficient concrete around the inlet/outlet pipes connections with the wall. Also, additional steel bars may be needed to reinforce the pipes to the walls.

13) The last layer of CHB_s is filled at only one-half full capacity. This is <u>important</u> to insure that the ring beam will attach to the wall more strongly.

14) Apply backfill behind every two CHB layer height. Backfilling should be gentle as the CHB_s are not yet completely set.



USE f2 GUIDE ON CENTER (NOT ON EDGE) OF CHB TO ACHIEVE CIRCULAR SHAPE.



PLACEMENT OF INLET/OUTLET DIPES AT ½ h. (SHOWN HERE OUTLET)

Figure 9: Wall Construction

3.2.6 <u>Ring Beam</u>

The ring beam is a crucial part of the structure: it is the <u>foundation of the dome</u>. The thrust and stresses of the dome can be counteracted by the ring beam to the soil.

Construction joints are utilized since the complete dome is not poured at one time (not monolithic). A banana stalk core (5 - 7 cm. diameter) is appropriate for making construction joints since it is easily workable and flexible to form a circle and that it is available at no cost at all.

Three circular reinforcement bars are needed for the ring beam, arranged with intermittent triangular stirrups (80 cm. spacing).

Forms are made of lumber (2" x 2" or 2" x 1"; 16" long) and lawanit/ plywood or GI sheets. There are no forms for the back of the ring beam; instead, backfill and the soil are used. (See ring beam diagram below.)

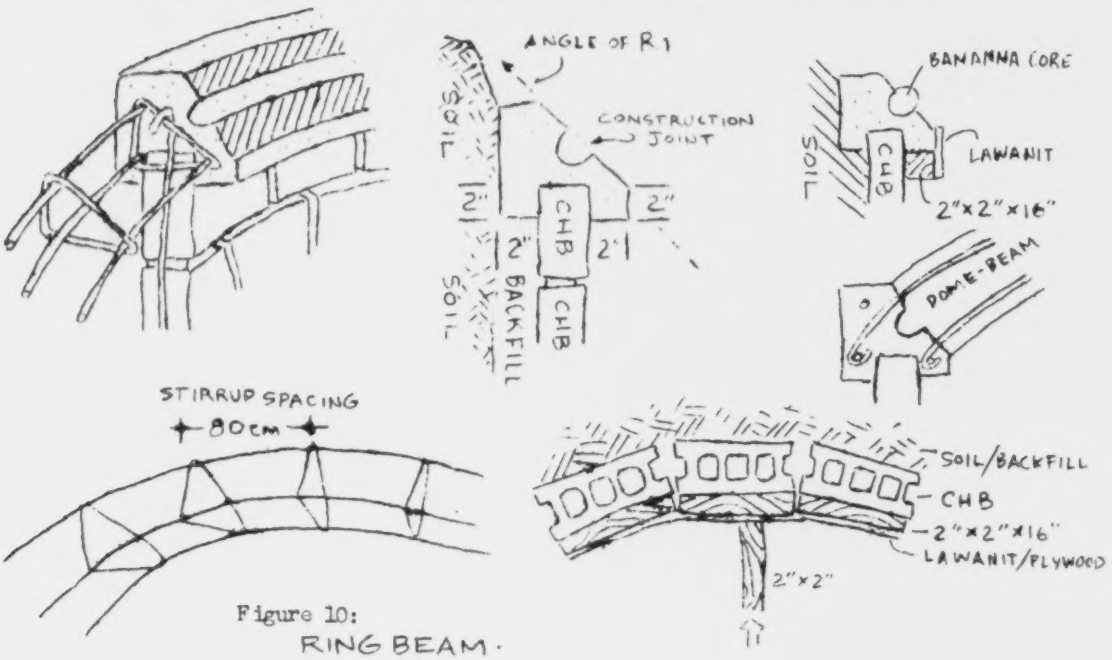


Figure 10:
RING BEAM.

3.2.7 Dome Beams (Arch or Cross Beams of the Dome)

Construction of the reinforced concrete beams and manhole collar is carried out simultaneously. The difficulty is in achieving the perfect curvature or arc of the dome. Hence, the procedure presented here for dome construction is somewhat difficult, costly and time consuming. However, when it is constructed correctly and according to specifications, the dome will be structurally strong and therefore less expensive in the long run.

Prior to dome beam construction is the preparation of the forms to obtain the specified dome curvature. This is done by drawing the "cross-section" of the dome, in scale on the ground (preferably on a concrete floor, using chalk), complete with the top CHB wall portion, ring beam, dome, manhole collar and sleeve (see diagram below).

In drawing the "cross-section" the following step-by-step procedures are taken:

1) Draw one long line. This will be the center-line of the digester. The length should be longer than R_1 distance.

2) Draw another line perpendicular to this line (or diameter of the digester). The intersection of the two lines will serve as the bottom point of "f_1".

3) Determine the radius length of the digester and mark off accordingly. Determine "f_1" distance and mark accordingly on the R_1 distance from the intersection.

4) Continue and draw the remaining according to the design/plan specifications: CHB, ring beam, dome curvature (using R_1 dimension given; "f_1" and the diameter points should meet on the R_1 curve; similar process as making the "f_2" form guide). Draw the manhole collar and sleeve. Remember, these are all drawn <u>in scale</u> on the ground.

5) Determine thickness of the dome beams according to specifications. Draw this on the "cross-section".

6) Place the lawanit/plywood on top of the drawing where the dome beams are located. This area is between the ring beam and the manhole collar. Using the R_1 distance and the "large compass technique" (used in making the "f_2" form guides described earlier), draw the <u>inside</u> and the <u>outside</u> curvature with the specified thickness of the dome beam on the lawanit/plywood sheet. The length of the beams will be the distance from the ring beam to the manhole collar. The angle corresponds to the R_1 angle.

7) Cut out this form and re-check for accuracy by placing the cut-out form on the "large" scaled cross-section on the ground. There are <u>four</u> dome beams and therefore a total of <u>eight</u> of these dome beam forms are needed. Use the first cut-out form as the pattern for cutting out remainder.

8) Prepare four bottom pieces for the four dome forms. The width will be specified according to the thickness, and the length will be the distance from the ring beam to the manhole collar with the curve.

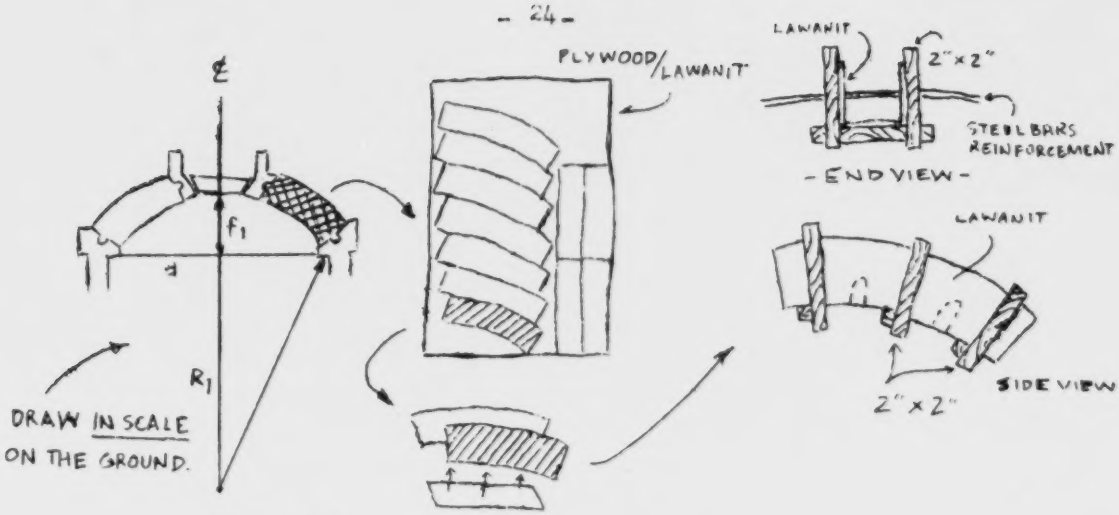


Figure 11:
DOME - BEAM FORMS PREPARATION

Having prepared the forms as described above, the next step is now to construct the dome beams using the following procedures (See diagram below):

1) Install the forms within the digester, using sufficient braces to hold them firmly and to support the weight of the concrete to be poured.

2) Install circular iron bar reinforcements, stirrups and manhole sleeve.

3) Place construction joints.

4) Pour concrete into forms layer by layer. Be careful in pouring since concrete is heavy and the forms may collapse. Tap concrete lightly with a hammer or "poke" with a stick periodically in the forms as concrete is being poured. This is to settle the concrete completely around the rods and eliminate air pockets.

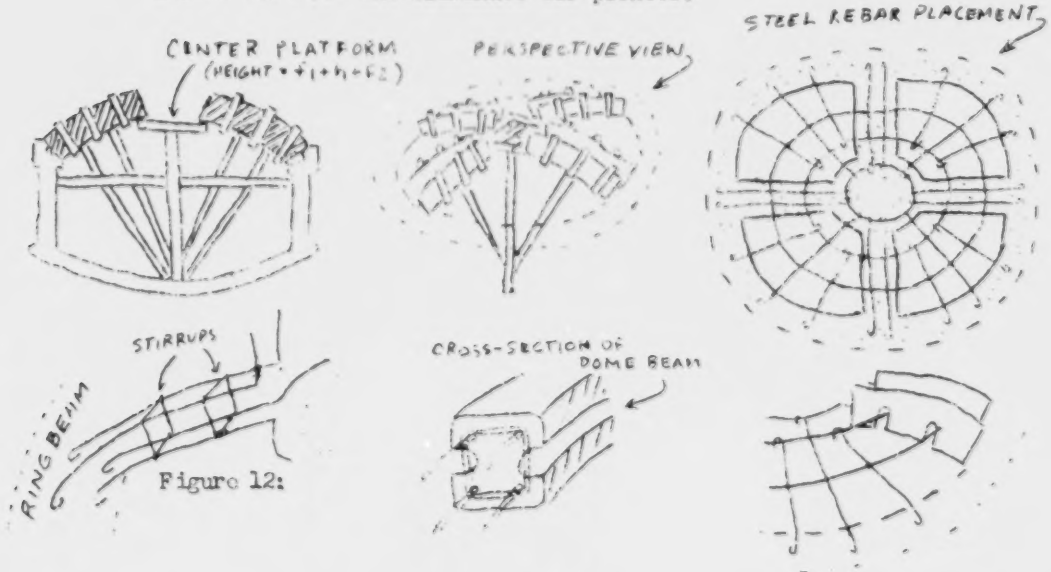


Figure 12:

3.2.8 Dome Quadrants

After the dome beams, the next to be constructed are the dome quadrants completing the dome structure (See diagram below).

The procedure in constructing them is as follows:

1) Remove all dome forms and clean "construction-joints" well of any debris. Extra care must be exercised in removing the forms and construction joints as pieces may break/fall off.

2) Prepare necessary forms, using lawanit/plywood, since it is easily bent or curved. Try to "flush" with the interior of the dome. Use as necessary braces to hold the forms in place (to support the poured-concrete weight).

3) Place reinforcement bars, and make sure they are properly spaced from the form materials. Add any additional reinforcement bars if necessary (again see diagram below), or use GI fencing wire for extra strength.

4) Pouring is done in two quadrants at a time. All joints should be "painted" with cement-water solution before actual pouring. Pour carefully and in layers instead of in "clumps". Use stick to "poke" concrete well into the construction joints. Place extra concrete to form mounds at all joints or seams or on all four edges of each quadrant.

5) Carry out concrete pouring job in one day or in one setting to avoid joints or seams.

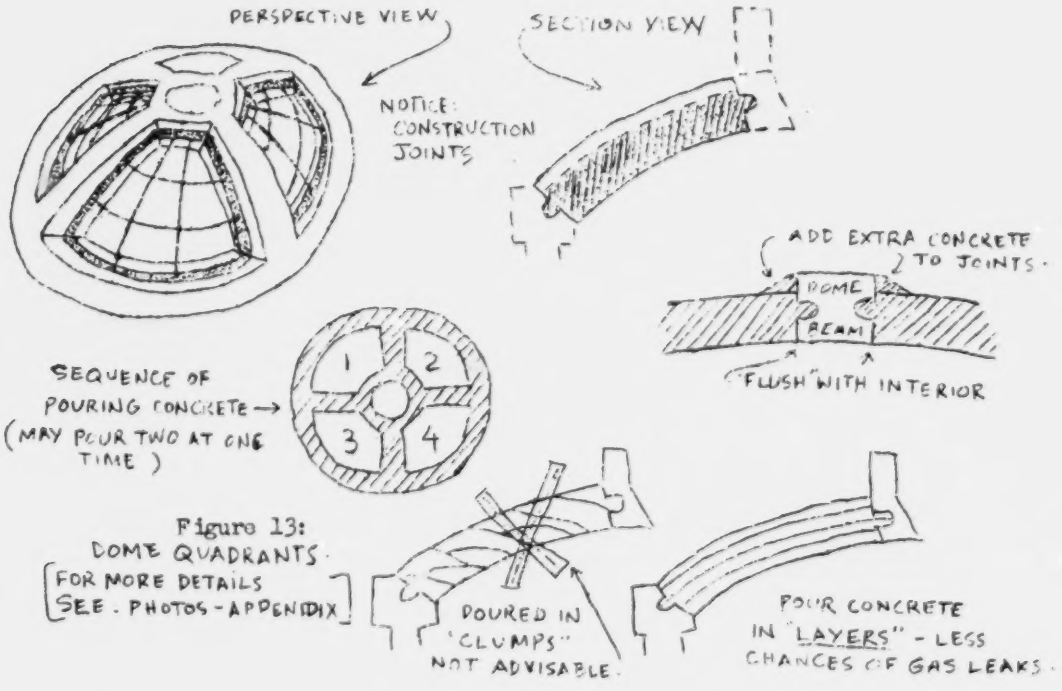


Figure 13:
DOME QUADRANTS.
[FOR MORE DETAILS SEE. PHOTOS - APPENDIX]

3.2.9 Outlet Chamber/Pit

As mentioned earlier, the outlet chamber is circular in shape. Its floor is at the same level as the ring beam and they are connected at that point. Since the correct level of slurry in the digester is up to the ring beam, it is easily visible from the outlet chamber when filling the digester. This is because the slurry will be at the floor level of the outlet chamber at a "zero" gas pressure within the digester.

The volume of the outlet pit is one-third of the digester volume.

The outlet chamber is made of CHBs, 4" x 8" x 16". This CHBs size is sufficient enough for all digester volumes, since this chamber is not exposed to stresses.

The procedures in constructing the chamber/pit are as follows:

1) The CHBs are cut in half lengthwise in order to obtain a small diameter circular pit.

2) Steel reinforcements are not necessary, but may be added if extra is available.

3) The flooring is flat and made of poured concrete with a smooth finish.

4) The inside of the chamber is plastered smoothly.

5) The chamber is provided with a simple cover that may be made of ordinary or corrugated, recycled GI sheets. The reasons for the cover is to prevent rainwater and debris from entering the pit, to keep children from falling in, to increase temperature of slurry, and to improve sanitation by keeping mosquitoes and flies from it.

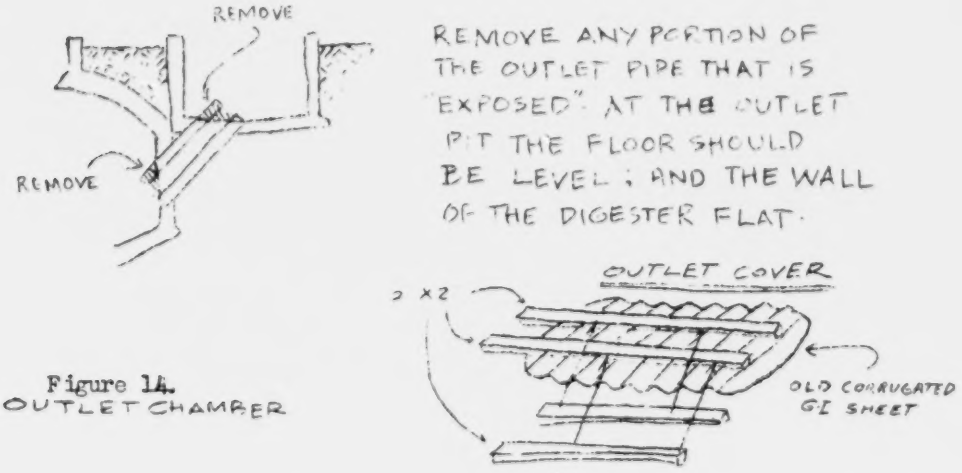

REMOVE
REMOVE
REMOVE ANY PORTION OF THE OUTLET PIPE THAT IS "EXPOSED". AT THE OUTLET PIT THE FLOOR SHOULD BE LEVEL; AND THE WALL OF THE DIGESTER FLAT.
OUTLET COVER
2 x 2
OLD CORRUGATED GI SHEET

Figure 14.
OUTLET CHAMBER

3.2.10 Mixing Pit/Inlet

The mixing pit performs the following functions:

1) To mix the slurry with correct consistency, that is, the right proportion to manure and water.

2) To mix and measure the proper amount of slurry to be charged per day.

3) To settle out any inorganic solids (sand, grit, etc.) so they do not get into the digester.

4) To remove any floating vegetable or other materials before the slurry is allowed to flow into the digester.

The mixing pit volume should be slightly larger than the daily charge volume so there is sufficient space for mixing the materials.

The mixing pit is circular, made of CHBs 4" x 8" x 16". Like the outlet chamber, the CHBs are cut in half to obtain a smaller diameter circular pit.

A wooden sluice gate is provided for the mixing pit to hold the slurry materials while it is being mixed and also to prevent excess rainwater from entering the digester. It should be watertight as much as possible.

Another component attached to the mixing pit is the inlet pipe which conveys the slurry to the digester. This requires an additional concrete pipe connected to the previously laid inlet pipe protruding from the digester wall. It is laid at the same angle as the first pipe so that the two adjoining inlet pipes are straight.

The procedures for laying the inlet/pipe are as follows:

1) Remove soil about 5 centimeters under and around the pipe connections so that there will be a good connection.

2) Make sure the two pipes are straight when connected to allow the periodic clearing of the inlet pipe with a stick or rod when it clogs.

3) Place a stone so that there will be a space for the concrete between the ends of the pipe where it is to be connected.

4) It is advisable to roll a plain GI sheet inside the point of connection to prevent concrete from falling into the pipes and to keep the inside of the pipes as smooth as possible.

5) Pour sufficient concrete to the joint and make it strong and clean.

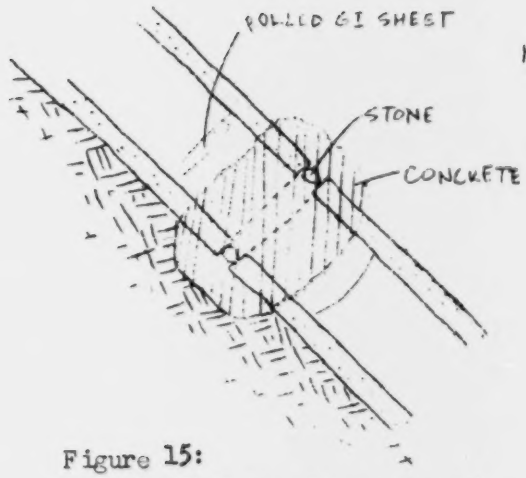


Figure 15:
INLET PIPE CONNECTION

3.2.11 Plastering

In the fixed-dome Chinese design, a major problem to overcome is gas leakage through concrete structure, particularly when the joints are not properly plastered. And the possibility of leakage is enchanced by the high gas pressure that this particular design digester encounters.

Efficient plastering of the inside walls of the digester and dome is therefore a very important part of biogas construction. The Chinese advocate multi-layer plastering with a final sealing layer of paraffin/wax solution. However, procedures vary slightly in different regions.

Plastering is a difficult work to master and the plastering of the digester must be performed professionally because the structure demands complete water and airtightness. The dome is extremely difficult to plaster because the area to be plastered is overhead and the surface is curved.

The following are some tips in plastering:

1) Always begin from bottom to top, not working in a sideward direction.

2) Avoid joints in plastering; if possible finish all plastering in one day. Joints may lead to leaks.

3) Don't mix more concrete mortar than can be used within one hour.

4) Use circular motion for plastering.

5) Provide a "rough" finish for the final plastering for the gas

portion of the digester dome. This is to provide a good adhering surface for the paraffin/wax application. Paraffin or wax does not adhere well to a smooth surface.

6) To further check if plastering is solidly done, examine the inner surface by "tapping" with a stick. If an area produces a "hollow-sound" when tapped, it is to be dug out and replastered. This is checked after the plaster has been dried.

7) Apply two layers of concrete plaster, 1 centimeter thick each layer.

8) Level off under the ring beam to avoid corners. (See diagram below.)

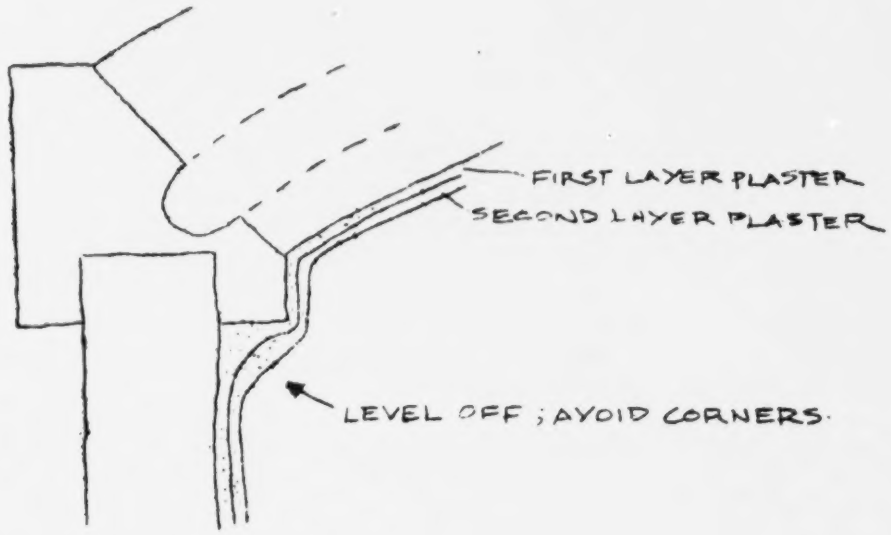


Figure 16.
LEVEL OFF UNDER THE RING-BEAM.

3.2.12 Flooring Finishing

After the plastering is completed the flooring can now be finished. Clean the inside of the digester and "joint of the flooring" to be connected with a steel brush and apply "cement-water solution". If the stirrer/mixer is to be incorporated in the unit, the mixer "center-pole guide" must be prepared beforehand. This will be placed at the bottom center of the digester (previously where the center stake was placed for the center-pole technique). Check again the center of the digester with a plumb bob.

In preparing for floor finishing:

1) Make sure that the reinforcement bars are clean and spaced evenly from the ground.

2) Place center-pole for use of the "f_2" form.

3) Using "f_2" form guide, pour concrete evenly according to the specified floor curvature. Pour from the outside towards the center.

4) Place the mixer "center-pole brace" at center. Check vertical and center position with the use of a plumb-bob.

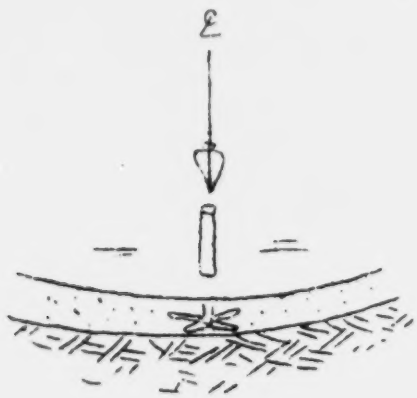


Figure 17.
MIXER CENTER-POLE GUIDE PLACEMENT.

3.2.13 Manhole Sleeve

The next to be finished is the manhole sleeve, involving the following steps:

1) Prepare forms and the specified reinforcement bars. (Note: if the mixer/stirrer assembly is to be incorporated prepare 3 bolts for the manhole cover brace.)

2) Keep all joints/connections clean.

3) Apply "cement-water solution" to all joints/connections prior to pouring concrete.

4) Pour concrete.

Note: the dimensions for the manhole and manhole sleeve are the same for all digester volumes.

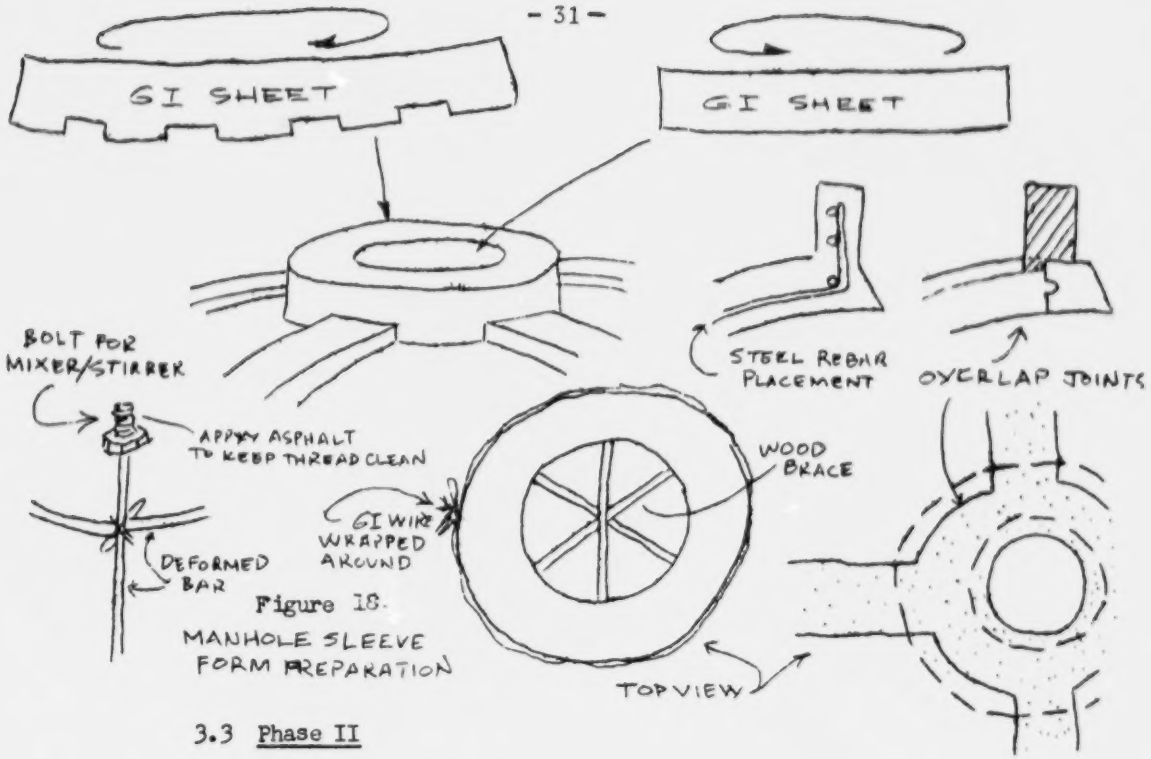


Figure 18.
MANHOLE SLEEVE FORM PREPARATION

3.3 Phase II

3.3.1 Paraffin/Wax Application

The different tools needed for this work are: a blowtorch, a paint brush 2½" size and may be slightly used, an old pot or tin can to melt the wax, a small bowl/can with wide mouth to hold the melted wax while being applied, and a steel brush.

As mentioned earlier, the sealing of the inside surface of the gas portion of the digester will be done at least 2 weeks after the concrete work has been completed.

The procedures involved in paraffin/wax application are as follows:

1) Inspect carefully the inside of the digester to see if:

   a) There are any cracks in the structure, or portions producing "hollow" sounds. If so, make appropriate repair jobs.

   b) The concrete structure exhibits some degree of dampness, that is, there is water visible. If so, check by spreading cement powder and observe if it "wets" the cement. If wetting is very slow, paraffin wax may relieve the small leak. If the leak rate is fast, concrete repair is necessary.

   c) There is water in the bottom. Remove it and check the next day. If water returns, there is a leak which has to

be repaired. Use dry cement powder technique to determine where the leak is coming from.

2) If there are no damages to the structure, clean the dome and digester walls of loose particles (concrete and sand bits) with steel brush. Remember a rough finish is more desirable since wax will adhere to the surface much better. This applies only for the gas portion of the structure.

3) Melt the wax. Add kerosene to the melted wax: 3 unit-volume of kerosene to every 10 unit-volume of wax. This is to lengthen the hardening time of wax and makes it more pliable and easier to work with. Then place the melted wax in a smaller, wide-mounthed container which will be easier to work with inside the digester. Be careful when adding kerosene over fire; it may ignite!

4) Allow the melted wax to cool off a little. Hot wax does not stick to concrete very well and instead the hot wax drips off the paint brush, wasting much of the wax and may also ruin the brush hairs. Besides, it is too hot to handle. A good sign of a workable temperature for wax is when it starts to develop "thin film" on the surface.

5) Apply the melted wax using a paint brush. This is a "tricky" procedure requiring practice and the following are a few pointers:

   a) Place the container always below the work area to collect any drippings. Wax is expensive. Another way of collecting the wax is to fill the bottom with water. This way the dripped wax floats and it is easily recovered.

   b) Apply with up-strokes and "splashing" the wax on the surface using the brush.

   c) Paint from the bottom of the ring beam and work up towards the manhole sleeve.

   d) When finishing a small area, use left-right-left and diagonal strokes. This assures that most of the area is applied with a wax layer.

   e) Place extra wax for jointed areas like under the ring beam, dome beams, manhole sleeve and gas pipe.

6) When the whole area has been applied with wax, smoothen it with the use of a <u>blowtorch</u> operating on medium-high flame. Also check for missed areas. You will notice that exposing the area to a blowtorch will render the wax finish into one smooth, homegenous/ continuous layer of wax and therefore gas tighting the area completely. Important: When using the blowtorch, do not let the

flame remain on one section too long. This will remove all wax and the excessive heat may crack the concrete plaster on the surface. Left to right and circular moving motions when blow-torching work best for desired results.

7) After blowtorching, there will be many minute holes visible. These need "touch-up" patching with another layer of wax to those areas and another blowtorch application. Inspect again and repeat if necessary.

8) Inspect the adhesion of wax to the surface being worked on. Repeat waxing if necessary.

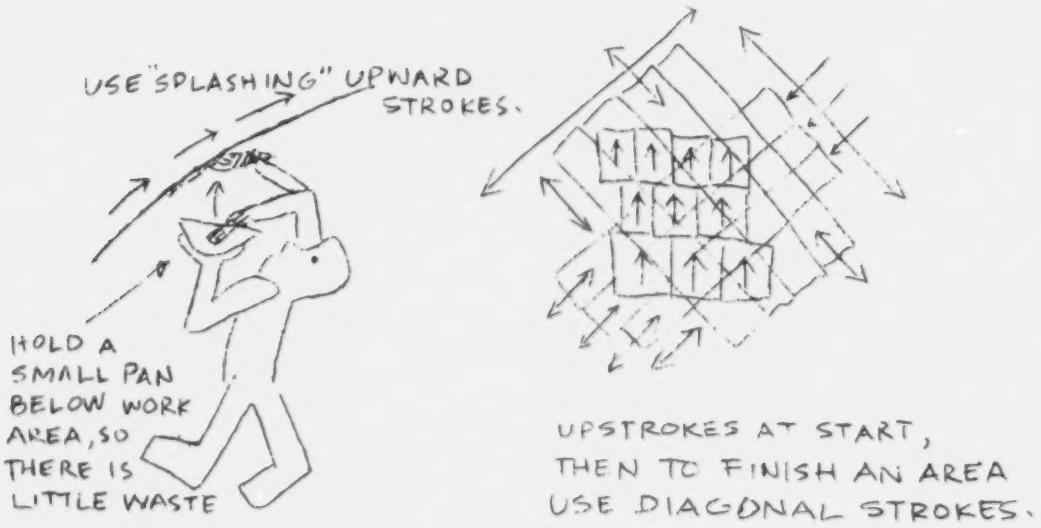

USE "SPLASHING" UPWARD STROKES.
HOLD A SMALL PAN BELOW WORK AREA, SO THERE IS LITTLE WASTE
UPSTROKES AT START, THEN TO FINISH AN AREA USE DIAGONAL STROKES.

Figure 19. WAX APPLICATION

3.3.2 Stirrer/Mixer Assembly

This component is primarily a welding job. (For specifications, refer to the design/plan in Appendix B .) However, in installing the assembly requires that the removable manhole brace (which are described and diagrammed in the next section) and mixer guide (placed in the concrete flooring) be prepared beforehand. The 3 piece "fan-blades" of the manhole brace has a pipe at the center where the three blades converge. The location of this pipe must be in such a way that when the brace is attached to the three bolts, which are already fixed on the manhole sleeve, the stirrer assembly will be perfectly centered on the digester and thus the mixer guide at the base of the digester.

An example of the bill of materials for the mixer/stirrer assembly for a 4.66 m^3 digester includes:

1) GI (ordinary) pipe, 1" dia. x 1' (mixer guide)

2) GI (ordinary) pipe, 1½" dia. x 10' (center shaft of mixer)

3) GI (ordinary) pipe, 2" dia. x 4' (mixer sleeve and manhole brace center pipe)

4) Flat bar, 3/16" thick x 4" x 10' (blades of mixer, the fans of manhole brace)

5) Angle bar, 1/8" thick x 1" x 10' (reinforcement for the blades)

6) GI coupling, 1 pc. 2" dia. (connects manhole brace and mixer sleeve)

7) GI Tee, 1 pc. 1½" dia. (placed at center shaft top for attaching mixer manual handle)

8) Cap screw, 12 pcs., 7/6" dia. x 1" (to attach blades to mixer center shaft - - 4 ea., for each blade.)

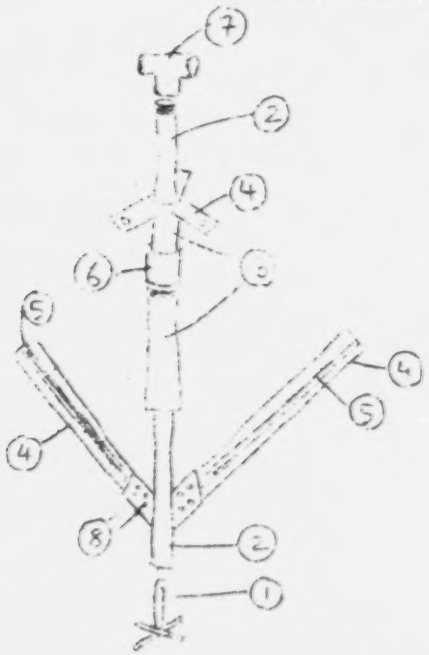


Figure 20. Stirrer

3.3.3 Removable Manhole Cover

As mentioned earlier, the size of a manhole cover is standard for all digester volumes. It is circular in shape, 65 centimeters in diameter and 12.5 centimeters thick. This thickness is sufficient to withstand the same pressures exerted on the sides and dome of the digester.

The removal of the manhole cover allows entry into the digester during cleaning, inspection and other maintenance activities. However, precaution must be observed when entering a digester which has been in operation for sometime. (The "Safety" precautions are discussed under topic on Maintenance and Operation.)

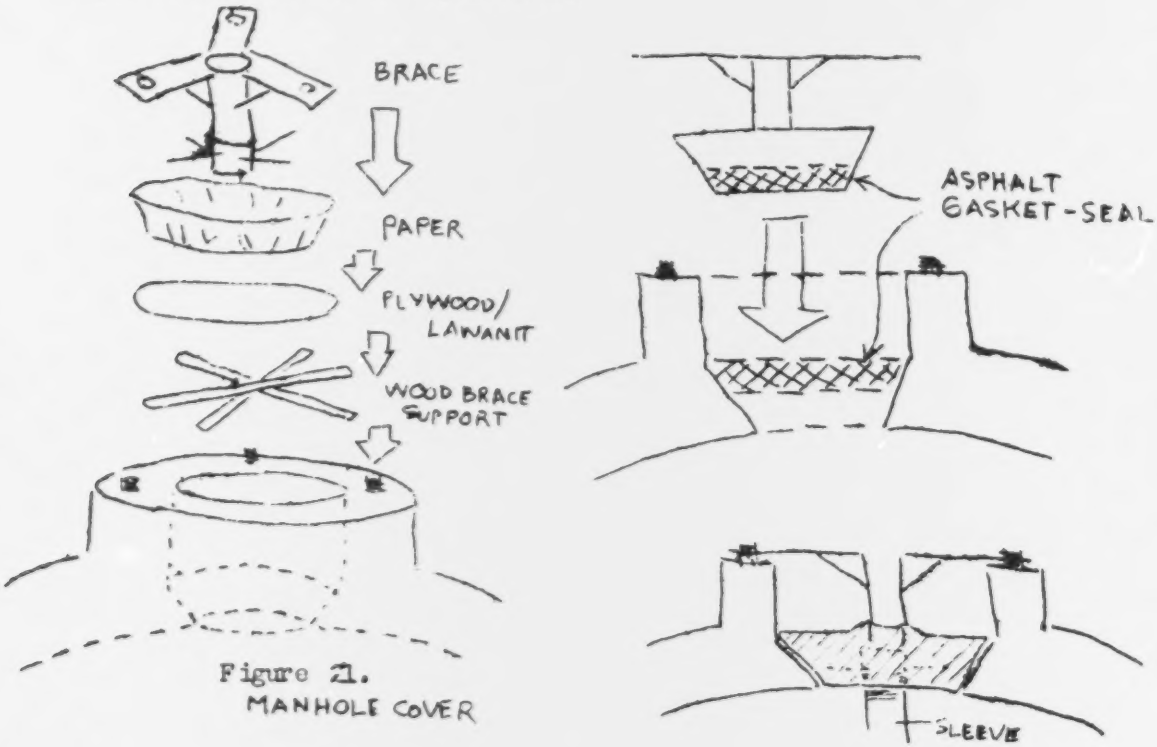


Figure 21.
MANHOLE COVER

3.3.4 Gas Piping System Components

The piping system generally consists of four components, namely: gas line, consensation trap, flame arrester and manometer.

1) Gas line. There are two alternative types of materials used in the system:

   a) GI pipe is recommended especially for outside use and in situations where ultra-violet rays or sunlight is of high intensity. 1/2" diameter pipes are sufficient for most purposes. It is expensive but long lasting and may rust

badly if laid on acidic soils. In installation, the number of elbows and coupling should be minimized, where possible, since they are expensive.

b) Flex tube, which is a heavy duty rubber hose with ply, is recommended in situations where turns/bends exist in the piping system and especially for indoor use. Ultra-violet rays deteriorates rubber tube quickly. Thus, when used outdoors, it should be protected from high sunglight exposure. 1/2" diameter pipes are generally used and which require 3/4" diameter rubber tubes for connections or elbows.

2) Condensation trap. Biogas contains moisture which "condenses" and must be removed. To solve this problem, the initial pipe leaving the digester should be sloped toward the digester so that the water will flow back automatically. If the pipe cannot be sloped, it is provided with a flex-piping joint so that it may be lifted up to ocassionally drain the water back into the digester. The condensation water should be checked every month.

3) Flame arrester. This is a safety devise in case of accidental backfire flame returning to the digester and which may cause an explosion..

This devise is simply a ball or roll of fine copper wire mesh inserted in the gas line. Do not place it too tightly as it may block the gas flow. Two points are recommended for this device to be located: one close to the digester and the other near the manometer or point of gas use.

4) Manometer. It serves 2 purposes, namely: a) as an indicator of gas pressure, and it shows the relative amount of gas in storage within the biogas plant, and b) as a safety device which automatically controls the build-up of excessive high level of gas pressure within the biogas tank.

The manometer to be used is easy to make. It is a water column mechanism consisting of a piece of 1/2" diameter plastic tube nailed on a plywood in a U-shaped form. One end is connected to the gas line and the other is left open. The plastic tube is then filled half-way with water to the "0" level on the manometer. The water will rise and fall at the open-ended side of the tube depending on the pressure exerted by the gas on the water column. At zero pressure, the water levels in the 2 sides of the U-shaped tube are equal. Calibrations on the plywood will be made, starting at zero on the point conoiding with the level of the water at zero gas pressure.

As gas pressure continuously builds up, the gas pushes the water column until the water spills from the tube, thus releasing the gas.

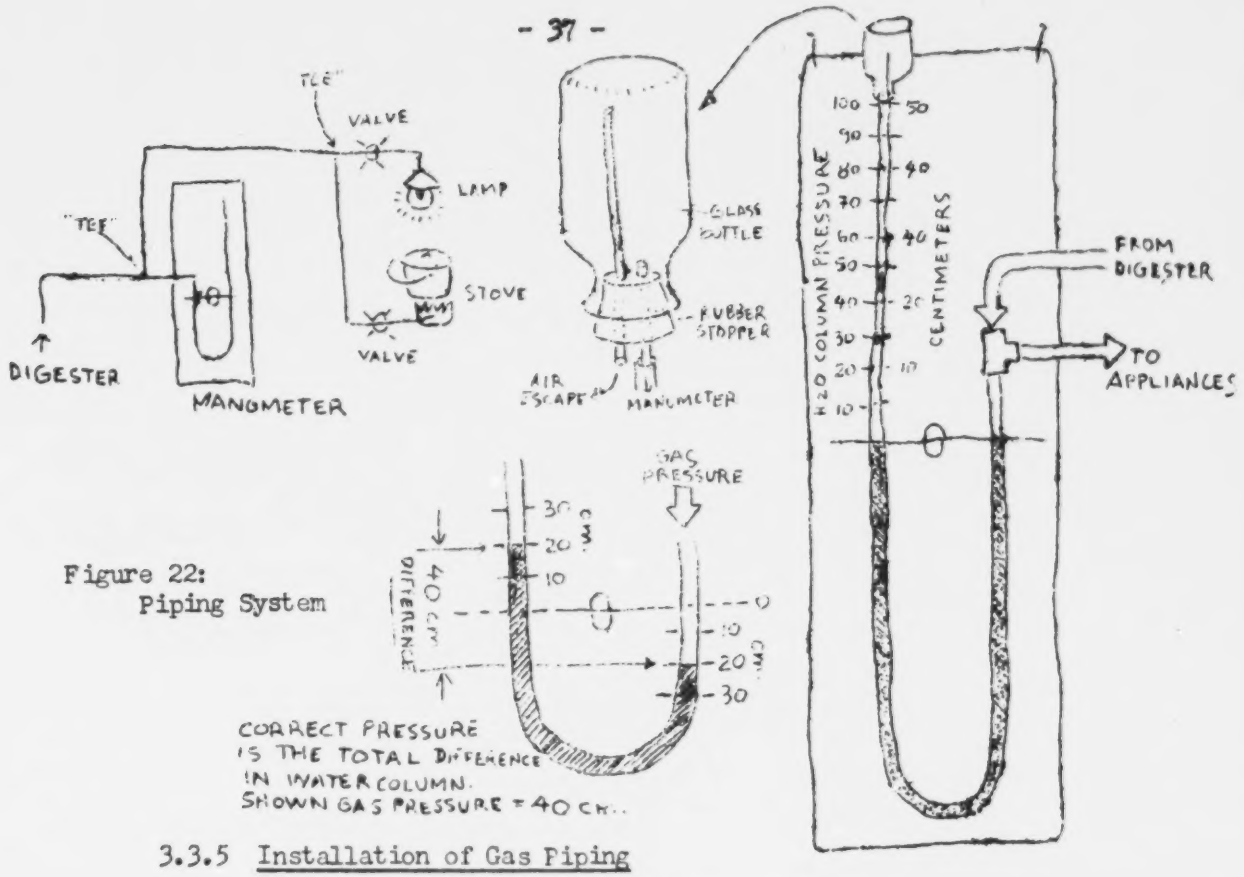


Figure 22:
Piping System

3.3.5 Installation of Gas Piping

The following procedure is recommended to be observed in installing the gas piping:

1) Test if possible all hoses, valves and connections before installation. Submerge them in water tub and "blow" air (using bicycle pump, for instance) and see if any leaks or bubbles appear.

2) Study beforehand how the piping system will be fitted/installed. Prepare a rough plan indicating the valves, fittings, manometer and how the gas piping will flow from the digester to the stove.

3) The valves and manometer should be fitted securely to the wall at a visible location for easy monitoring.

4) Reduce the number of connections between valves, hoses and fittings to reduce chances of leaks.

3.3.6 Backfilling

Seven days after the whole unit is completed, backfilling may be done. Until then allow concrete dome to "cure" properly; otherwise the structure will be damaged by the backfill weight (For proper curing of concrete, refer to Appendix H.)

Ideally the mixture of the backfill should be 30% gravel or broken stones and 70% soil.

The backfill area should be well sloped to allow easy drainage of surface water. Water should not stand around the digester. A small trench may be provided so that water is easily drained.

Grass and plants but not trees, are recommended to be grown on the backfilled area.

3.3.7 Testing for Water Leakage

The digester must have to be finally tested for water tightness. To do this is fill the digester half with water and periodically measure the water level for several days. If water level drops, there is a leak somewhere in the tank.

When leaks occur, it is advisable to make a thorough check of the digester for any possible defective masonry work.

A large quantity of water is needed for this test. The procedure involved is as follows:

1) Fill the digester with water up to the inlet and outlet pipes level.

2) Let it set for 3-5 hours until the tank walls are saturated with water, mark the water level.

3) Let it set overnight. A significant drop in water level indicates leaks on the walls or the flooring.

4) When the water level no longer drops, a mark on the wall should again be made. This shows that the leak occurs between the first mark (Item 2) and this second mark.

5) Locate the source of leaks or any cracks. Use the wooden end of a hammer to lightly tap the area. If an empty or hollow sound is detected, the concrete should remove and redone.

6) Fill with water again and repeat test for water tightness.

3.3.8 Testing for Gas Leakage

This should follow the water tightness test. The steps are:

1) Close and seal the manhole as well as all the gas valves.

2) Begin to add water through the inlet to increase the air pressure inside the digester until the manometer registers 40

centimeters of water column. Or air may be blown into the digester up to the same pressure.

3) Leave the water in the digester for 24 hours.

4) If the drop in pressure is very small, say 1-2 centimeters, the digester is gas tight. But if the drop is noticeable, or more than 5 centimeters, the dome is not gas tight.

5) Be sure there are no leaks in the piping system. Repair the leaks accordingly.

Having insured the water and gas tightness of the digester, the unit is now ready for loading.

4.0 OPERATION AND MAINTENANCE

Many biogas units have not produced as much gas as they should and many others have just gone out of use. A properly built structure and sufficiently available raw materials may not produce the desired results due to faulty operation and/or poor maintenance. The People's Republic of China, for instance, observed that generally success in biogas production is 30% due to structural or building process and 70% to proper operation and maintenance of the unit.

4.1 Initial Loading

Proper initial loading contributes to the eventual good performance of the unit. There are a number of guides to keep in mind.

1) Starter/Seeding. The initial raw materials should contain slurry with a high bacteria population. This is the "starter". About 5-10% of the total slurry volume should be added when the digester is about 25% full.

Cattle dung is a good starter since cattle have methane producing bacteria in their stomachs. Starter can also be made from any manure by adding to it 5-10% "old" slurry obtained when cleaning the digester. Starter can be prepared by storing manure in a container while constructing the digester. At the time the digester is completed, the manure will reach a sufficient bacteria population.

2) Filling the Digester. The digester should be filled as quickly as possible. The following steps are involved in doing this:

a) Before putting any slurry into the digester, be sure to first open all valves to relieve any built-up pressure in

the digester dome. It is advisable not to connect the piping system to the digester when loading.

b) Mix manure and water thoroughly until there are no more "lumps" and the mixture will assume a "thick pea-soup" or "thick mungbean-soup" consistency. This will increase gas production since the bacteria will have more "surface" contact with the manure.

c) Fill up to the ring beam level, which is the same level as the outlet chamber floor. Check again to insure that there is not build-up of pressure at this time within the digester.

d) Do not add any new slurry to the digester until at least 3 days after burnable gas is produced.

3) Care should be taken that the following materials will not enter the digester:

a) Earth or sand - - for it causes problem by hastening the accumulation of such materials within the digester. These materials should be allowed to "settle-out" while mixing the slurry in the mixing pit, before allowing them into the digester.

b) Straw, grasses, leaves, etc. - - since these materials will "float" on the surface of the slurry and cause "scum" problem which may consequently reduce gas production. Remove all floating materials at the mixing pit before allowing them into the digester.

c) Oil, soap, detergent, disinfectant, etc. - - these materials will disrupt bacteria activity or may even kill the bacteria.

4.2 Mixing Slurry for Regular Loading

About 1 liter of water is usually added to every kilo of manure. As in the initial loading, the slurry should be mixed thoroughly until the right or "thick pea-soup" consistency is obtained. However, in actual practice, there is no fixed water-manure proportion since this will depend on the type of manure being used and its moisture content. The technique will be developed through experience. The material that should not get into the digester as previously mentioned should be strictly observed, sea water and brackish water with a high content of salts and impurities should not used in the mixture.

4.3 Regular Loading of Input Materials and Removal of Effluent from Outlet Chamber

The loading of materials should be done regularly. Ideally it should be daily. The amount of slurry should be in accordance with the requirement

of the particular digester volume and its retention time. Less slurry being loaded than what is required would result in poor gas production since the bacteria will be "starved"; likewise, excess slurry will result in raw material wastage since the slurry will not able to be fully digested.

The loading of new slurry materials displaced an equal volume of effluent to the outlet chamber. This effluent must be removed. Otherwise the digester would be overloaded. One way to check correct digester level is that at zero gas pressure, the slurry should be at the level of the outlet chamber floor.

4.4 Stirring/Agitation

Mechanically disturbing the slurry inside the digester with the use of the stirrer performs two vital functions: first, to stimulate bacterial activity; and second, to break the "scum" layer which forms a mat of vegetable/organic matter at the slurry surface and this restricts gas flow through the slurry to the gas holder. If left undisturbed, the scum would get thick and harden, which may require opening the digester to remove it.

Stirring should be done daily - - 3 minutes in the morning and 3 minutes in the afternoon. The stirring should be 360° in one direction, then 360° in the opposite direction.

4.5 Condensate Removal

The condensate or water that settles in the piping system must be removed monthly since condensate accumilation may obstruct gas flow. This condensate removal may be done by lifting the gas pipe so that the water in the pipes will be drained back into the digester.

4.6 Servicing Scum Problem

The steps in removing scum are as follows:

1) Release all gas within the digester. Manometer reading should be zero.

2) Disconnect gas piping closest to the digester.

3) Remove manhole.

4) Inspect the scum layer and check its thickness.

5) Remove scum manually with buckets through the manhole.

Caution: In removing the scum, be cautious about presence of fire nearby. Smoking near the digester is dangerous. The digester still contains gas and may explode!

4.7 Periodic Cleaning of the Digester

The digester may need to be emptied at intervals to remove the settled sludge and other inorganic solids, like sands and stones that accumilate~ at the bottom of the digester. The materials are removed manually through the manhole, with the use of buckets or pumps. This is also an occasion to check for any possible leaks and structural damages.

Take necessary precautions when entering a digester. There are poisonous gases inside.

Apart from the regular schedule, complete emptying of the digester should be done if the following conditions occur:

1) Stirring becomes too difficult due to heavy accumulation of inorganic solids (sand, pebbles, etc.) and/or the presence of thick scum.

2) Gas production ceases completely. This may be due to the introduction of toxins (detergents or disinfectants) into the slurry.

3) Gas production slows down despite regular daily loading and stirring. There may be leaks in the structure.

4.8 Repairing Masonry Work Within the Digester

Due to a variety of causes, a need to repair the digester may arise. If the damage is serious, the wall or a whole section may have to be rebuilt. But normally, the damage is only in the form of cracks or leaks and repair work would be much easier.

The technique for locating a damaged area was discussed earlier pp. 38-39. Repairing the damaged area involves the following procedures:

1) Clean the damaged portion. Inspect and determine extent of damage.

2) Carefully chisel a wide "V"-shaped groove. Roughen the edges.

3) Attach 2-3 layers of chicken wire to the wall with nails at least 30 centimeters from either side of the crack. (See illustration below.)

4) Apply cement-water paste to the entire area. This is to insure good adhesion.

5) Plaster cement-sand (1:3) mortar at least 13 millimeters thick. Roughen the finish.

6) Allow to dry for at least 2 weeks. Inspect.

7) Apply wax/paraffin seal.

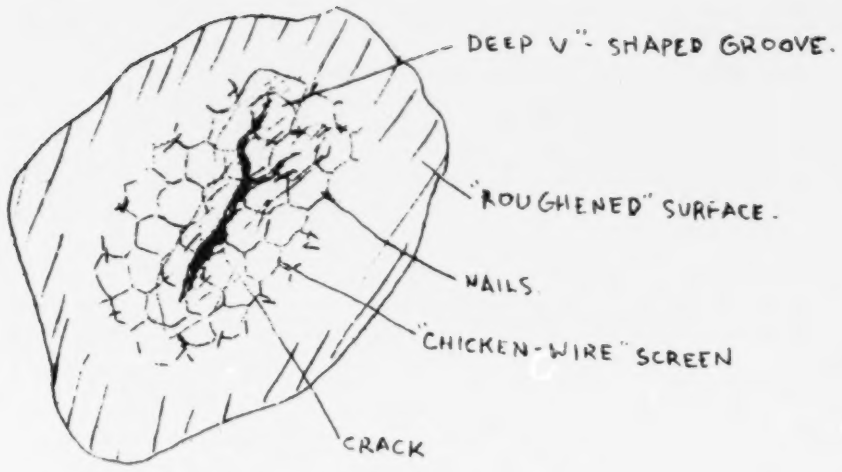


Figure 23. REPAIRING "CRACKS" IN MASONRY WORK "CHICKEN-WIRE" REINFORCING.

4.9 Entering The Digester

The following should be observed when planning to enter, or upon entering, the digester which has been in use for some time:

1) Remove manhole cover for several days.

2) Disconnect gas line closest to the digester.

3) Remove contents of the digester through the manhole with buckets or a pump.

4) Ventilate the empty tank. A completely empty digester is likely to have carbon dioxide gas "lying" at the bottom. The gas should be removed either by "blowing-out" with fresh air or "lifted-up" by buckets. Allowing wind to recirculate within the digester with the use of air pump is advisable.

5) Before anyone enters the digester, it is best to check presence of harmful gases or of sufficient air, with a small animal (e.g. chicken, rabbits, etc.). This is a simple method used in the People's Republic of China. The animal is lowered in a small cage into the digester and brought up after a few minutes. If the animal behaves normally, this indicates that entering the digester dies not pose any danger. If something unusual happens to the animal, like fainting for instance, it indicates lack of sufficient air circulation or ventilation inside the digester. Repeat test until satisfactory. One must always enter the tank with caution.

6) Use only flashlights inside the digester. No smoking or open flames (candles, laterns, etc.) near or within the digester.

7) Prepare a long piece of pipe or hose (one end attached outside of the pit) through which the worker inside the pit may breath. Also it is advisable to have a second person to pull him out if he accidentally loses consciousness. Any feeling of dizziness or discomfort in breathing is enough warning for the person to get out of the digester. He should rest and take fresh air. It is not advisable for one person alone to do the work. Someone should be constantly watching from the outside of the pit who can respond to any emergency. A safety line should be attached to the worker inside.

4.10 Gas Utilization

It must be pointed out again that biogas is a clean fuel -- non-toxic, odorless and smokeless. It has a blue flame. Chemically, biogas contains 60-70% methane (CH_4), 30-35% carbon dioxide (CO_2) and less than 1% other trace gases, particularly, hydrogen sulfide (H_2S), hydrogen (H_2), carbon monoxide (CO), and nitrogen (N_2).

In the rural areas the two most potential uses of biogas are for cooking and lighting, and also running kerosene-fed refrigerators.

The efficiency of gas use is largely determined by a suitable mixture of gas and air that enter the appliance and in turn is dependent on the following factors:

1) Pressure. The Chinese biogas digester unit generates variable pressure, thus there may be a need for frequent adjustment. Gas pressures above 20-centimeter water column give satisfactory results. This is adequate to force gas and air into the appliance. At pressures less than 20-centimeter water column, gas-air mixture may not reach the appliance. In this case, there is a need to adjust the "mouthpiece" further into the appliance, and re-adjust as gas pressure increases again. Remember that if the mouthpiece is too far from the appliance, there will be lack of air to the mixture.

2) Efficiency of the appliances used. A gas efficient-appliance should have the following basic features:

   a) Inlet channel should be smooth to reduce resistance of the gas-air flow.

   b) Spacing and size of air holes should be proper.

   c) Volume of gas-air mixing channel should be large enough for complete mixing.

d) Gas jet holes should not be too large nor too small but just large enough to allow for easy passage of mixed gas and air.

e) Appliance should be simple, economical, and cheap to make or purchase, but at the same time be durable.

In using a stove, it would be helpful to observe the following:

1) A good flame is a pale blue in color, strong and even, and also produces a "hissing" sound.

2) If the flame shifts around or is unsteady, it may due to either insufficient air, or too large holes in the gas-feed tube. Adjustment is necessary.

3) If the flame has a red or yellow tint, this may mean either that there is too much air or gas intake or that the gas-feed tube needs to be enlarged.

In using the gas for lamps or lighting, the following are important guides:

1) First use the lamp without a mantle. Check if the flame is pointed down, pale blue in color, and burning evenly with a "hissing" sound. If so, the lamp is good and the mantle may now be attached.

2) Use denatured alcohol to soak and ignite the mantle. Leave the gas petcock off until all the alcohol has burned off. This provides the mantle to be "white".

3) Now light the lamp. If the flame wanders, this indicates either of two things: there is insufficient air and the gas tube has to be raised; or the gas-feed tube is too large which has to be changed to a smaller one.

4) If the flame is reddish, it either means there is not enough gas of there is too much air. Push the gas-feed tube further into the lamp, or make the gas-feed tube hole larger, or it may be due to mantle quality, or may be due to a high CO_2 content of the gas. Frequent adjustment and experiment are needed until the desired results are produced.

For making your own lamp, see Appendix K.)

4.11 Biofertilizer (or Effluent) Utilization

As mentioned in the introductory part of this manual, the other two benefits from biogas production are efficient disposal of wastes and the generation of organic fertilizers after the wastes have been acted upon by bacteria within the digester.

It is estimated that 70 percent of the total solids put into the digester comes out as effluent or fertilizer material. This contains almost the same nutrients that were initially put in, but through the decomposition process the nitrogen and other elements are retained and in the form that is more readily available to plants. It is unlike composting, or letting the manure decompose in the open, where most of the nutrients are lost by leaching and volatization.

The importance of organic fertilizers cannot be overemphasized. They provide vital functions in improving the fertility and productive capability of the soil particularly in terms of increasing its humus content, microbial activity, porosity and water-holding capacity. Furthermore, effluent fertilizer retains its fertility residual effect in the soil for about 3 years compared to that of chemical fertilizers which is about one year.

On the health and environmental sanitation aspects, the effluent is considerably "freer" from disease-carrying organisms than is fresh manure. Most of the bacteria and other pathogens are killed in the process of digestion, primarily due to the absence of oxygen, presence of ammonia and other conditions that exist inside the digester. Furthermore, dilution of the manure with water results in settling of worms and eggs to the bottom of the tank. The design of the Chinese biogas unit is such that the inlet/outlet pipes are half-way up the wall to insure that most of these parasites are not discharged until sufficient time has elapsed for their destruction.

Extensive research in the People's Republic of China have shown the effectiveness of biogas digesters in treating manure. 2/ Comparison of fecal liquid introduced into biogas units with that of the effluent showed that the number of parasite eggs was reduced by 93.6% and hookworm by 99%, while shistosomiasis v flukes disappeared and the number of dead ascaries was high. Eggs of parasites can survive in a biogas tank for 14 days in autumn and 36 days in winter. Ninety percent of hookworm eggs died within 30 days in winter and 99% filariasis parasites died during the same length of time in summer. Experiments on bacterial viability showed that E. Coli index was reduced, the shigeela v hucellus and the spirochetes, which oxygen-needing bacteria, died.

2/ FAO Soils Bulletin No. 40, "China: Recyling of Organic Wastes in Agriculture;" FAO/UNDP, Rome 1977, and FAO Soils Bulletin No. 41, "Azolla Preparation and Small-scale Biogas Technology", FAO/UNDP, Rome 1978.

4.12 Troubleshooting: Common Operational Problems And Their Remedies

Defects/Symptoms	Possible Causes	Remedies
Initial Loading Problems:		
1) Pressure does not rise	a) Very few bacteria	- Have patience, wait for sometime
		- Introduce "starter" slurry (approx. 20 liters)
		- Stir/mix contents
	b) Lack of time	- Have patience (without "starter" and colder temperatures, it would take 2-3 weeks for gas to appear)
	c) Leak in digester or gas pipeline	- Locate leaks and repair
	d) Gas leaks at slove valves	- Locate leaks and close valves
2) First gas produced does not burn	a) Wrong kind of gas	- Gas should be released. It may not burn since it contains the initial air in the gas storage area.
	b) Air in the gas line	- The air should be released until there is definite smell of biogas
	c) Feeding in fresh slurry while waiting for gas pressure to rise	- This is a common fault. No slurry should be fed into the digester until the third day after burnable gas has been produced.

Defects/Symptoms	Possible Causes	Remedies
3) Gas pressure goes	a) Gas valve for stove or lamp is open	- Close valves.
	b) Major leak in digester or gas line	- Locate leak and repair
4) Gas pressure rises very slowly	a) Temperature is too low	- It is normal; gas produced is always reduced during colder weather.
	b) Thick "scum" builds up in the digester	- Stir/mix two times daily. If serious, may need to remove scum manually through the manhole.
	c) Too much or too little slurry put in daily.	- Correct amount should be "charged" daily/regularly. This should correct itself in a few weeks.
	d) Putting toxic substances (e.g. soaps, chemicals, etc.) into the slurry.	- The toxic substances may have killed the bacteria and stopped gas production. If no gas in 3 weeks and bad odor of slurry is observed, clean out digester and refill.
	e) Gas leakage	- Locate leaks and repair
	f) Slurry is too thick or too thin within the digester.	- Correct the slurry consistency. This should correct itself in a few weeks.
Stoves:		
5) Gas will not burn	a) Air in gas pipe	- Allow some gas to escape until a definite smell of biogas appears.

Defects/Symptoms	Possible Causes	Remedies
	b) Wrong kind of gas (probably CO_2)	- Allow gas to escape until "0" manometer pressure. Wait until the unit corrects itself.
		- Wait for enough time for gas to be produced.
6) Flames are long and weak, or start far from flame ports, or does not stay lit.	a) Incorrect air supply	- Place pot in stove and adjust air/fuel mixture of stove.
	b) Excessive gas pressure	- Adjust and reduce pressure at stove valve.
7) Small flame	a) Insufficient gas pressure	- Flexible plastic piping gone flat at some places. Locate and repair.
	b) Gas jets partially blocked	- Clean out jets of stove.
	c) Gas line blocked with foreign matter	- Locate blockage and remove foreign materials.
8) Flame pulsates	a) Condensation of water in pipeline	- Remove or allow condensation water to flow back into the digester.
		-
9) No gas at stove	a) Main gas valve closed	- Open main gas valve.
	b) Condensation water completely blocked gas line	- Remove condesnation water as described earlier.
	c) Stove gas jet blocked	- Clean gas jet.

Defects/Symptoms	Possible Causes	Remedies
Lamps:		
10) Light is poor	a) Air/fuel regulator need adjustment	- Adjust accordingly
	b) Gas pressure is too low	- 20 cm. manometer pressure is sufficient.
11) Mantle breaks frequently	a) Gas pressure is too high	- Jet nozzle is too close to the diffuser. Set jet nozzle further from the diffuser.
	b) Wrong type of mantle	- Use correct type of mantle.
	c) Flying insects	- Provide appropriate type of cover/protector for the mantle, like glass or screen.
12) No gas at lamp	a) Lamp gas jet is blocked	- Gas regulator should be cleared. Inspect and clean.
Slurry Inlet/Outlet:		
13) Slurry does not flow into the digester	a) Inlet pipe blocked	- Clear inlet pipe by moving a long pole up and down until the pipe is cleared.
14) Slurry level at outlet is very high, but "0" pressure at manometer	a) Too much slurry in the digester	- Remove slurry from outlet and correct slurry level.
15) Excessive high pressure but low effluent level in outlet chamber	a) Outlet pipe blocked	- Clear outlet pipe by moving a long pole up and down until the pipe is cleared.
	b) Sluury too thick	- Adjust to correct slurry consistency.

Defects/Symptoms	Possible Causes	Remedies
Manometer:		
16) Manometer pressure is high but when valve is opened, manometer pressure drops immediately. Closing the valve manometer pressure returns to high pressure. Flame is weak.	a) Blocks in gas outlet or gas line, creating gas flow problems.	- Inspect gas outlet and gas line. Clear lines of any blockage or water.
17) When gas valve is opened, manometer water level fluctuates continuously. Flame is alternatingly strong and weak.	a) Water condensate in gas line. Gas flow is not steady.	- Remove water condensate in gas line.
18) When gas valve is closed, manometer level fluctuates continuously.	a) Leaks and/or presence of water condensate in gas line.	- Repair the leaking section; remove water condensate in gas line.
19) Manometer pressure rises rapidly when pressure is low, but rate of increase drops as pressure rises. And upon reaching a certain pressure, no further change occurs.	a) Rate of gas leakage is directly proportional to gas pressure, the higher the gas pressure, the greater the gas leakage.	- Inspect the gas section of the digester and repair the leaking area.
20) Gas production started normally, but the manometer pressure begins to drop or does not rise at all.	a) Leaks at gas line, at the manhole, at the dome, and/or on the digester wall.	- Inspect the gas line, manhole and dome for leaks. If none at these places, inspect the inside of the digester. Make appropriate repairs.
	b) Insufficient raw materials for fermentation; hence gas production is low.	- Add fresh raw materials for fermentation on a scheduled basis and at proper level.

Defects/Symptoms	Possible Causes	Remedies
	c) Toxins introduced into the digester that killed the bacteria, and therefore stopped gas production.	- Take a sample of slurry in a glass jar. Observe after 24 hours. If no bubbles are visible, then the bacteria has died. Clean the digester completely and refill.
21) Manometer gas pressure	a) Blockage at inlet/outlet pipes, resulting in no flow of slurry and in turn leaving no gas space available.	- Clear inlet/outlet pipes using a long pole. Slurry consistency may be inspected and corrected.

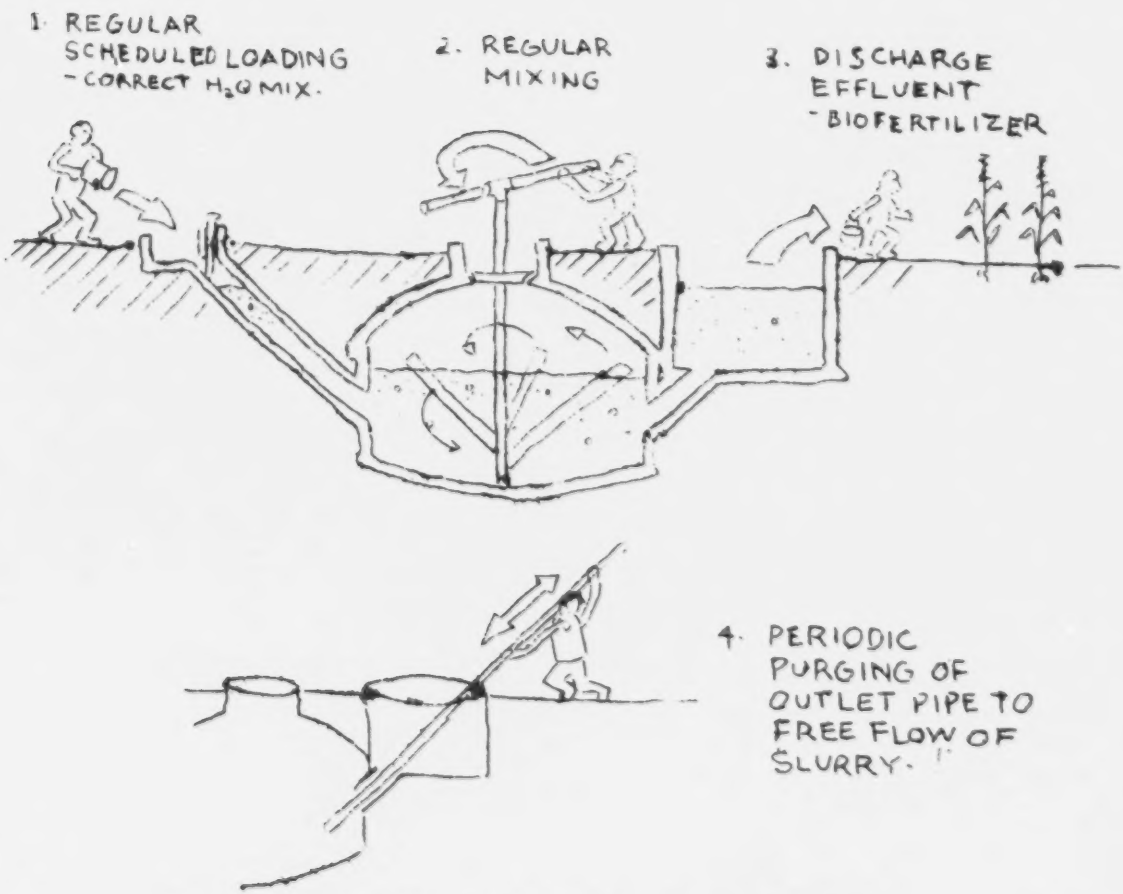

1. REGULAR SCHEDULED LOADING - CORRECT H_2O MIX.
2. REGULAR MIXING
3. DISCHARGE EFFLUENT - BIOFERTILIZER
4. PERIODIC PURGING OF OUTLET PIPE TO FREE FLOW OF SLURRY.

Figure 23. Operation and Maintenance of a Digester

Appendix A

THE BIOGAS PROCESS: A BRIEF INTRODUCTION

Biogas production is the process of decomposing organic materials (animals and plants) by bacteria under anaerobic conditions or in the absence of oxygen. The biogas thus generated is a mixture of 60-70% methane (CH_4), 30-35% carbon dioxide (CO_2) and the remaining consists of hydrogen sulfide (H_2S), hydrogen gas (H_2), nitrogen gas (N_2), carbon monoxide (CO), and other gases.

It is the methane content of the biogas that is flammable and is an excellent source of fuel. Carbon dioxide does not burn.

The production of biogas is naturally occuring around us, in ponds for instance where organic materials and bacteria are present under suitable conditions (i.e. anaerobic conditions, pH, etc.). But in nature the gas generated is simply lost to the atmosphere.

Hence the need to construct a biogas digester which enables us to control and accelerate the process and capture the valuable gas.

And we not only derive gas from a biogas digester, but also organic fertilizer/soil conditioner from what remains of the materials after being digested by the bacteria. In addition, the digestion process provides an excellent disposal system since it destroys disease carrying pathogens and parasites so commonly associated with decomposing organic materials.

In operation, the digester is full of slurry, which is a mixture of manure and water. Fresh slurry is prepared daily in the mixing pit and then fed into the digester. Likewise, an equal volume of effluent (or digested slurry) is taken out from the digester through the outlet pit, which may be "stored" in a nearby pit for eventual fertilizer use. The gas produced is collected in the gas chamber or dome portion of the digester and is directly conveyed via pipes to the house for use. This is how a digester essentially functions.

Inside the digester are millions of bacteria, which "digest" the slurry and in the process producing biogas and leaving a residue of organic matter and water. The biogas "bubbles" force their way through the slurry and gas begins to accumulate inside the gas-storage dome until it is to be used.

Basically, the digestion of organic wastes may be separated into two distinct processes, each process being carried by a specific group of bacteria.

The first group is the acid-forming bacteria which break down complex organic compounds into simple organic acids (primarily acetic acid and propionic acid). Other by-products of this process are ammonia and carbon dioxide. These bacteria are not very sensitive to their environment (i.e. temperature, pH, presence of O_2, etc.) and reproduce rapidly.

Appendix A (Cont.)

Under average Philippine climatic conditions, the retention time is about 40 days. Given the digester (slurry) volume, the daily input is accordingly determined.

(See Appendix for relationship between temperature and retention time.)

3) pH or Degree of Acidity or Alkalinity of the Slurry. Methane forming bacteria are sensitive to pH conditions and changes. Their optimum range is between pH 6.8-7.2 although they may tolerate a pH level of 6.5-8.0.

Under acidic condition, the methane producing bacteria cannot consume all of the acids being produced by the acid-forming bacteria and may stop digestion. To remedy this, add lime, grass ashes and wait.

If alkaline, the acidic carbon dioxide produced during digestion will correct the condition overtime. Have patience and wait.

To determine whether the slurry is acidic or alkaline, a Litmus paper test is being used. Since the pH (litmus) paper only shows extreme changes in pH levels, this test is used only when gas production has ceased and the probable cause is due to pH problems.

4) Carbon-Nitrogen (C:N) Ratio. Bacteria need both carbon and nitrogen to survive. They consume carbon about 25-35 times faster than they consume nitrogen. Thus, proper digestion proceeds at an optimum rate when the carbon content of the slurry or input materials used is about 30 times the nitrogen content (or C:N Ratio = 30:1), all other things being favorable.

The common sources of carbon are leaves, grasses and raw materials rich in cellulose. Those of nitrogen are manure and urine.

Check specific raw input materials value for approximate C:N ratio guide. (See Appendix for C:N ratio guide.)

5) Kind of Raw Materials Used. As mentioned earlier, toxic substances added to the manure and other input materials will affect bacterial activity and at high concentrations, toxic substances may kill all bacteria within the digester. Extreme care should be taken to insure that materials with disinfectants, detergents and other chemicals are not allowed to enter the digester.

Appendix A (Cont.)

The second group is the methane forming bacteria which further break down the simple organic acids, mainly acetic and propionic acids, into methane and carbon dioxide (or biogas). They are very sensitive to their environment and reproduce very slowly.

In a properly operating digester, these two groups of bacteria live together in balance. The acid-formers "provide food" for the methane-formers which in turn further convert it to produce biogas. But the balance may be disrupted when the acid-formers increase in activity, resulting in creating an acid condition which does inhibit gas production.

In other words, we are "culturing" within a biogas digester a population of bacteria and providing them proper food and suitable environment so they will effectively supply us with valuable by-products.

The major factors which stimulate gas production are temperature, retention time, pH (or hydrogen ion concentration), carbon-nitrogen ratio, and the "kind" of raw materials used. Note that these factors are directly related to the biogas fermentation process or to the creating of a suitable environment for the methane-producing bacteria within the digester.

1) Temperature. Generally, higher temperatures and less fluctuations in temperature are conducive to higher level of microbiological action. The temperature range at which normal anaerobic fermentation takes place is 18° - 32°C, reaching an optimal level of activity at 35°C. At 10°C bacterial activity ceases, and thus gas production stops. Wide changes or fluctuations in temperature are harmful to the anaerobic bacteria.

   It is primarily for the reason that the Chinese design is completely underground in order to minimize the adverse effects of fluctuations in ambient temperature.

2) Retention time. Retention time is the theoretical time that one daily sample of input material remains in the digester before it is expelled. Temperature is directly related to retention time; the higher the temperature, the shorter is the retention time. This is an important relationship to be observed in the operation of a biogas unit in that the volume of slurry input should be such that sufficient time is given for the bacteria to digest the material before it leaves the digester.

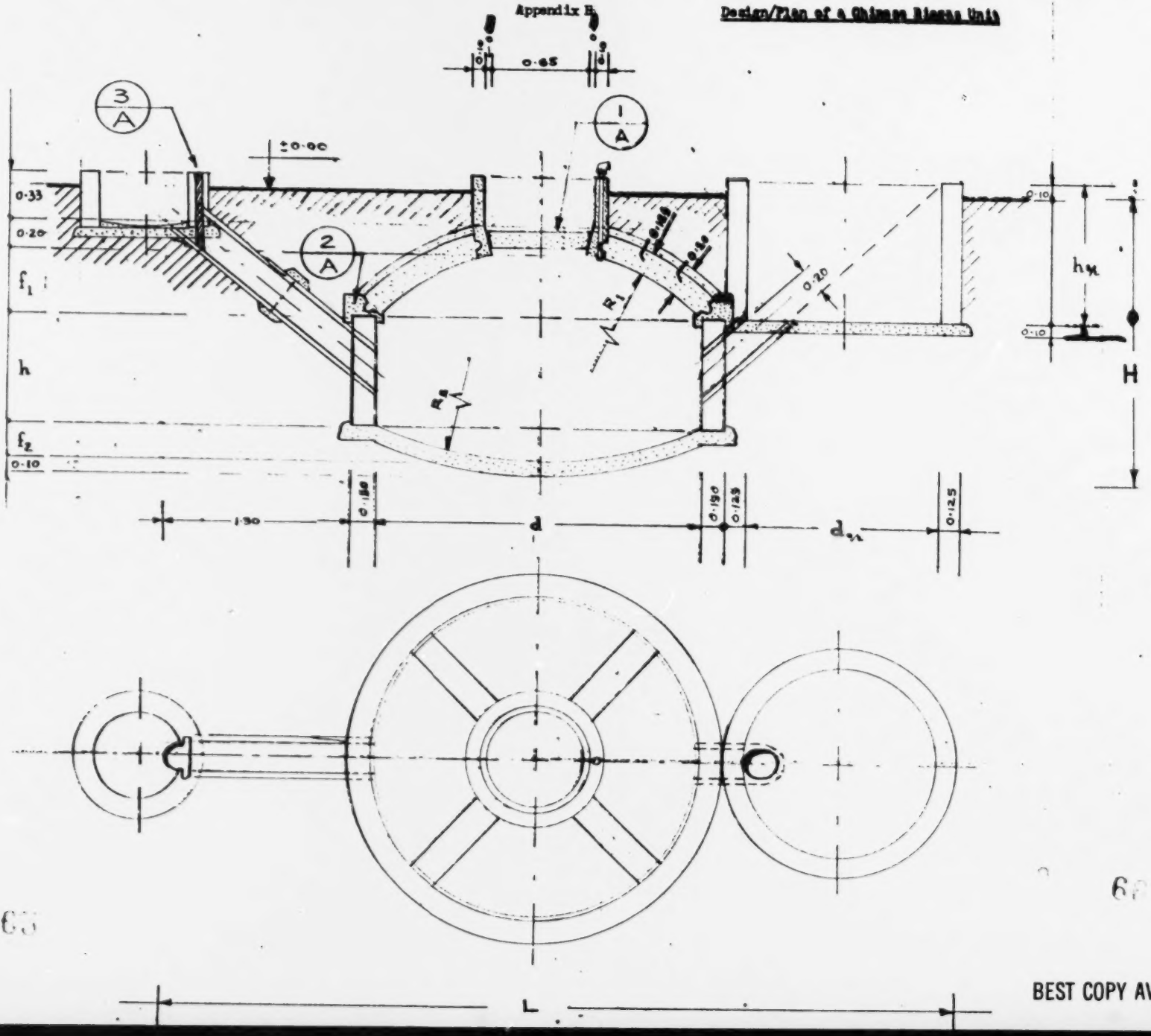
   Theoretically, retention time equals volume of digester divided by daily input, thus:

$$\text{RT (in days)} = \frac{\text{digester (slurry) volume}}{\text{daily input volume}}$$

   or, Digester (slurry) volume = RT x daily input.

Appendix B

Design/Plan of a Chimney Biogas Unit



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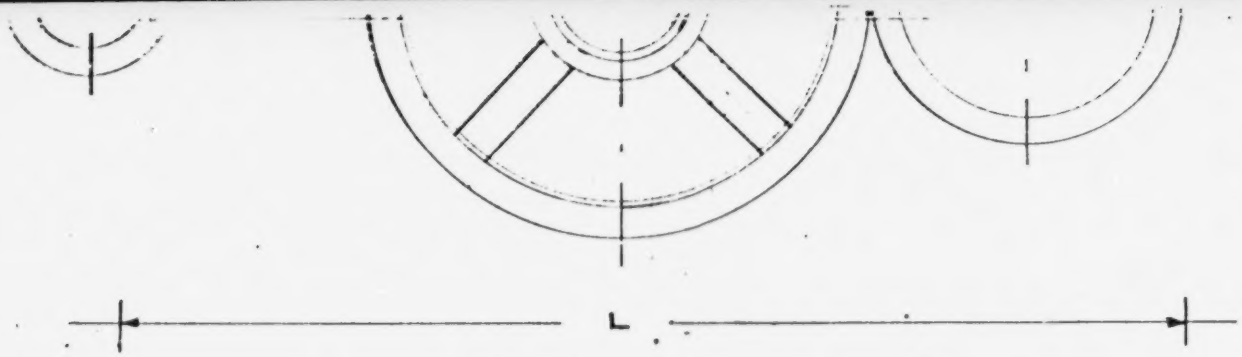

MEASUREMENTS IN METERS !!!

m^3	L	H	d	h	f_1	f_2	R_1	R_2	$d_{o/L}$	$h_{o/L}$	V_1	V_2	V_3
4.66	5.5	[illegible]	2.3	0.766	0.46	0.23	1.55	2.8	[illegible]	0.98	1.08	3.18	0.45
6.14	5.8	2.32	2.5	0.83	0.52	0.25	1.9	3.2	1.45	1.04	1.46	4.07	0.61
8.66	6.3	2.56	2.7	[illegible]	0.6	0.34	2.0	3.6	1.65	1.12	2.03	5.72	0.91
10.27	6.75	2.62	3.0	1.0	0.6	0.3	2.2	4.1	1.8	1.12	2.15	7.0	1.12
15	7.45	2.97	3.5	1.2	0.7	0.35	2.5	4.7	2.0	1.22	3.5	9.6	1.74

CHINESE BIOGAS DIGESTER

PLAN AND SECTION VIEW

- POURED REINFORCED-CONCRETE TYPE DOME
- DESIGN BY CHARLES H. NAKAGAWA, U.S. PEACE CORPS/PHILIPPINES; PHILIPPINE RURAL RECONSTRUCTION MOVEMENT (P.R.R.M.)

CODE NR 1/4

DESIGN NR

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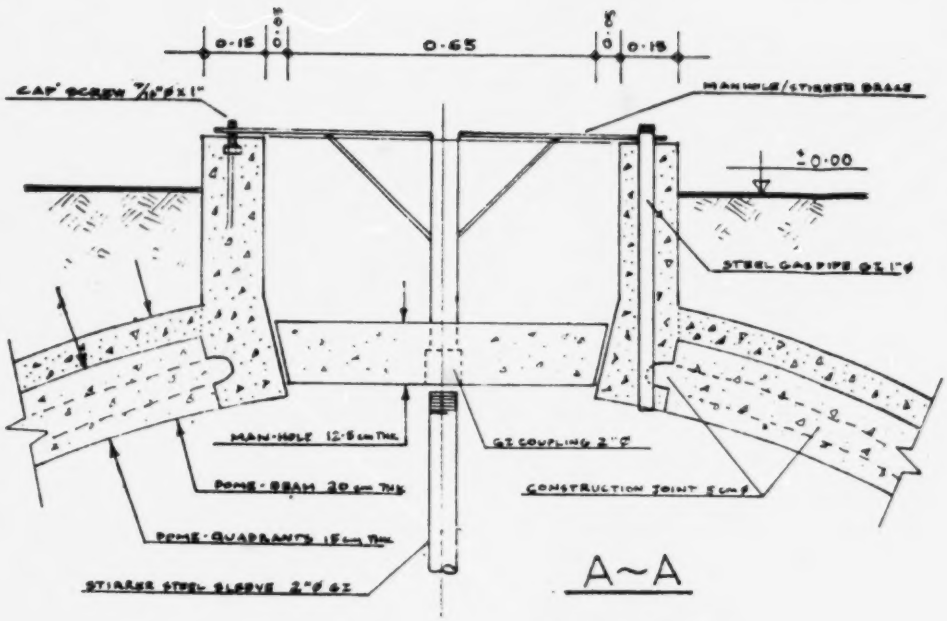
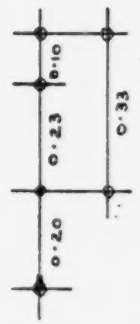
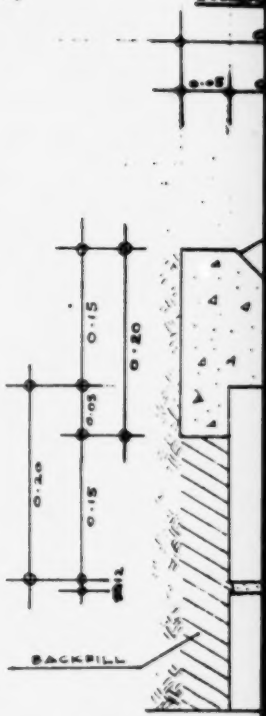
Appendix B (Cont.)

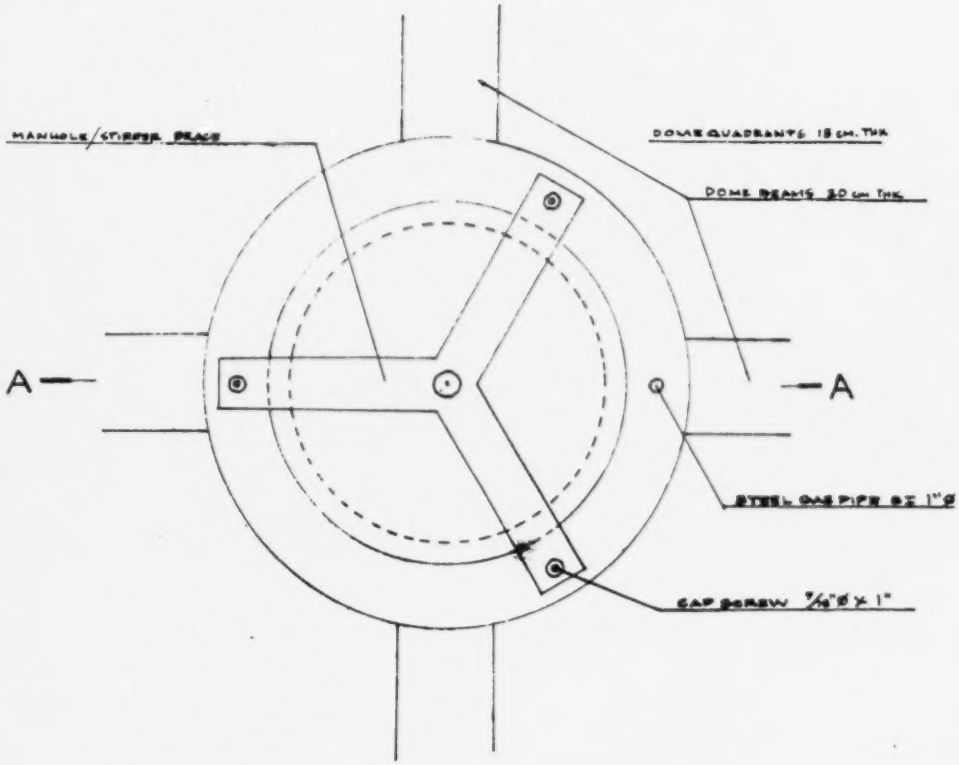


A~A

SCALE 1:10







NOTES:

1. REINFORCEMENT I
2. FURTHER DETAILS IN
3. CONSTRUCTION-JOI DOME-BEAMS AND CONJUNCTIONS O
4. CONCRETE HOLLOW SHOWN HERE ARE 4 m³ AND 6 m³. US

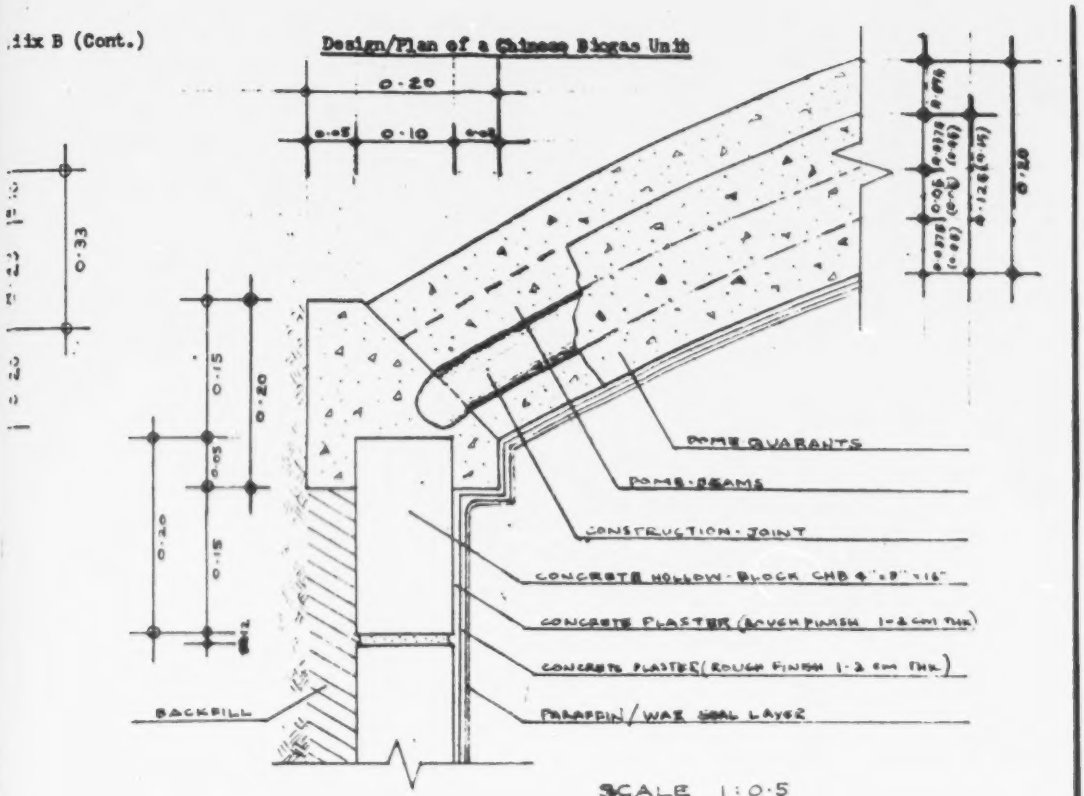
- ALL MEABUREMENT

CHINESE BIO

DETAILS OF SECTIO
- MAN-HOLE
- RING-BEAM

.11x B (Cont.)

Design/Plan of a Chinese Biogas Unit



SCALE 1:0.5

NOTES:

1. REINFORCEMENT IRON BARS NOT SHOWN HERE.
2. FURTHER DETAILS OF STIRRER/MIXER ASSEMBLY SHOWN IN
3. CONSTRUCTION JOINTS ARE MADE ON THE RING-BEAM, DOME-BEAMS AND THE MAN-HOLE SLEEVE. AT ALL CONJUNCTIONS OF THE DOME QUADRANTS.
4. CONCRETE HOLLOW-BLOCKS FOR WALL CONSTRUCTION SHOWN HERE ARE C.H.B. 4"x8"x16". THIS IS ONLY FOR 4 m^3 AND 6 m^3. USE C.H.B. 6"x8"x16" FOR 8 m^3, 10 m^3 AND 15 m^3.

- ALL MEABUREMENTS IN METERS (UNLESS STATED OTHERWISE)!!!

CHINESE BIOGAS DIGESTER

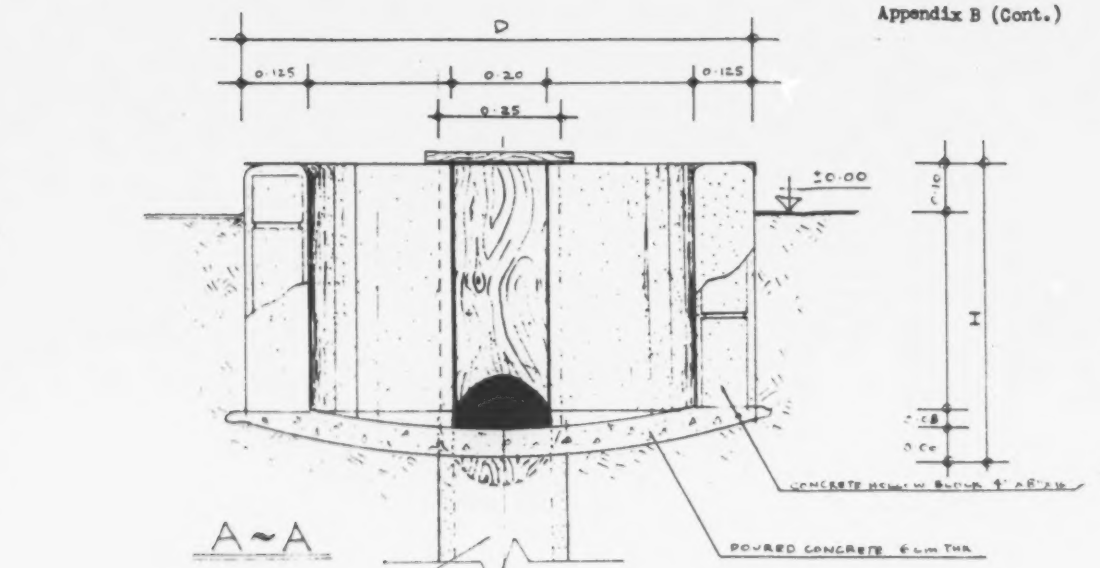
DETAILS OF SECTIONS AND CONJUNCTIONS
- MAN-HOLE SLEEVE AND COVER
- RING-BEAM

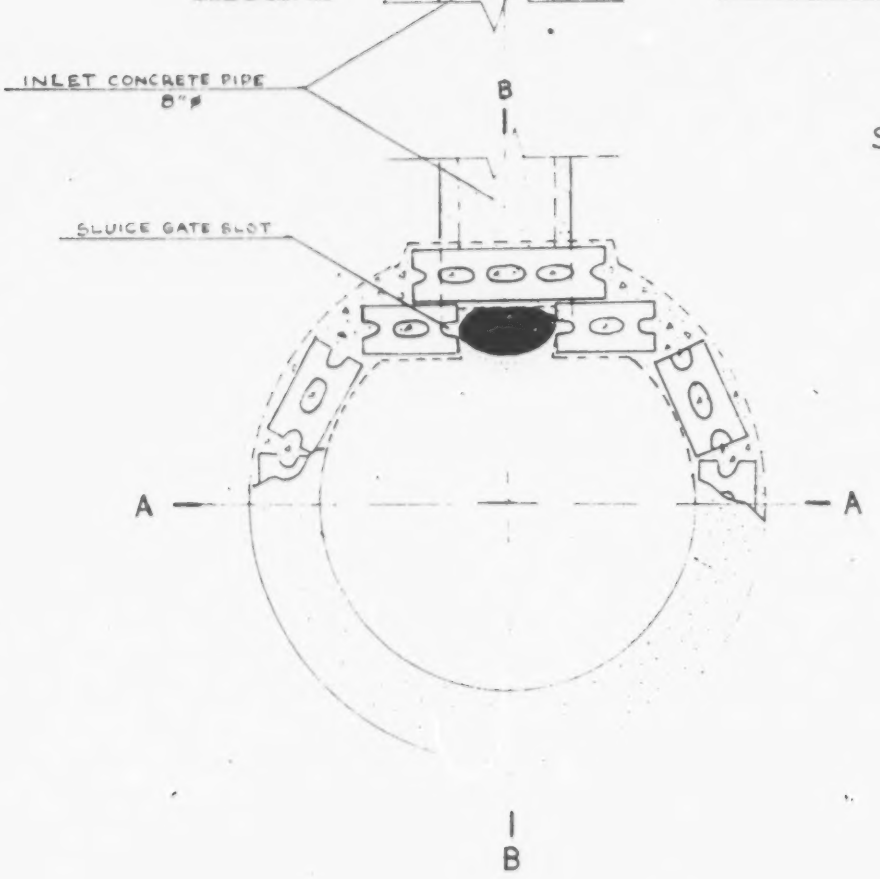
DRAWN/DESIGN BY CHARLES H. NAKAGAWA
U.S. PEACE CORPS/PHILIPPINES :: PHILIPPINE RURAL RECONSTRUCTION

2/4

JULY 1981

Appendix B (Cont.)





SLUICE GATE
W/HANDLE

WOODEN TYPE
1" THK x 10"

NOTES:

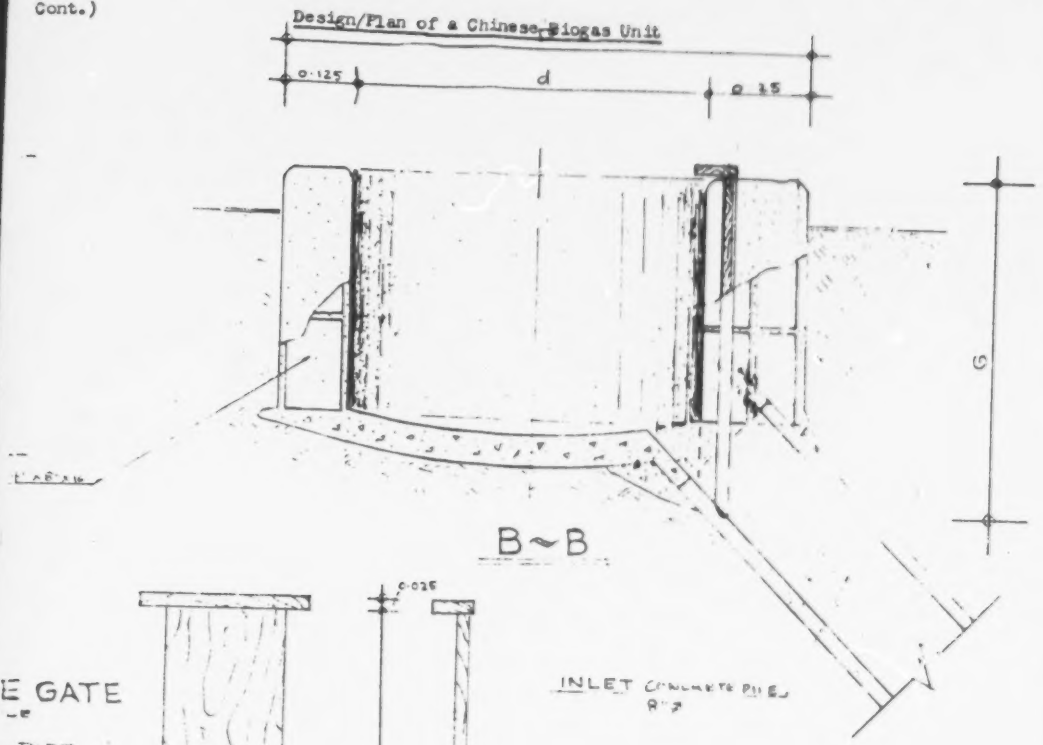
1. VOLUME OF MIXING
2. NOTICE CONCAVED FLO
   SOLID PARTICLES (SA
3. DISTANCE FROM END OF

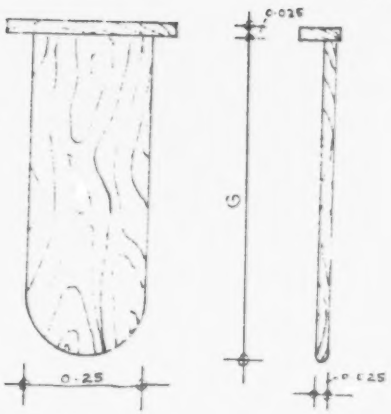
ALL MEASUREMENTS

CHINESE BIOGA
DETAILS OF SEC
- INLET / MIXIN
SLUICE GAT

Cont.)

Design/Plan of a Chinese Biogas Unit





E GATE

TYPE

NOTES:

1. VOLUME OF MIXING PIT SHOULD EQUAL LOADING VOLUME.
2. NOTICE CONCAVED FLOOR SO AS TO "TRAP"/SETTLE ANY INORGANIC SOLID PARTICLES (SAND, GRAVEL, ETC) BEFORE CHARGING.
3. DISTANCE FROM END OF CULVERT PIPE TO THE DIGESTER WALL IS APPROX. 1·3 m.

ALL MEASUREMENTS IN METERS (UNLESS STATED OTHERWISE) !!!!

CHINESE BIOGAS DIGESTER

DETAILS OF SECTIONS AND CONJUNCTIONS

- INLET / MIXING PIT

SLUICE GATE

NOT SHOWN: COVER

DRAWN/DESIGN BY CHARLES H. NAKAGAWA
U.S PEACE CORPS/PHILIPPINES ... PHILIPPINE RURAL RECONSTRUCTION MOVEMENT

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JULY 1981

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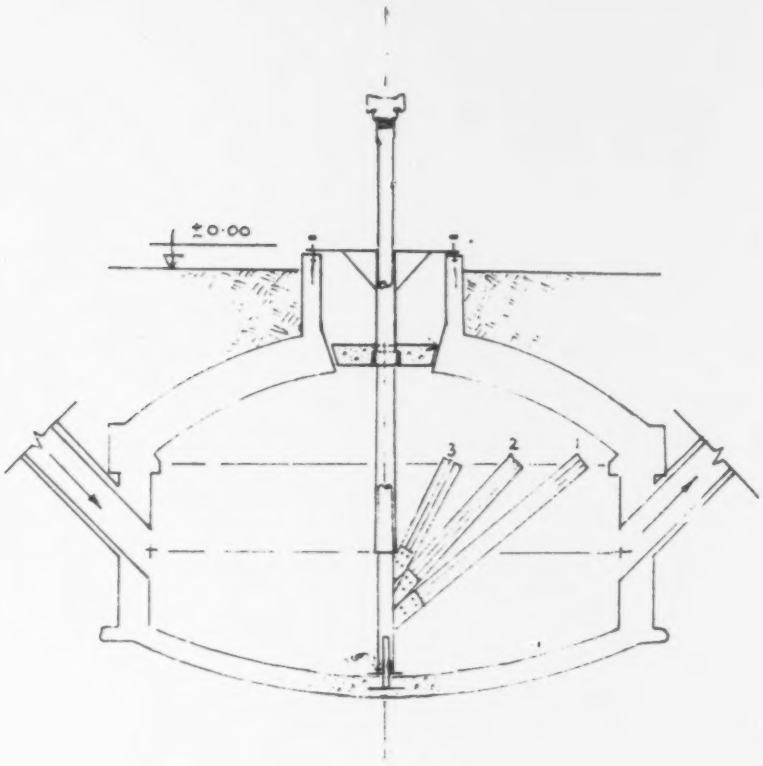
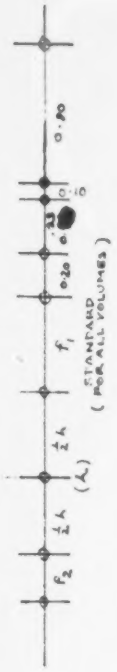
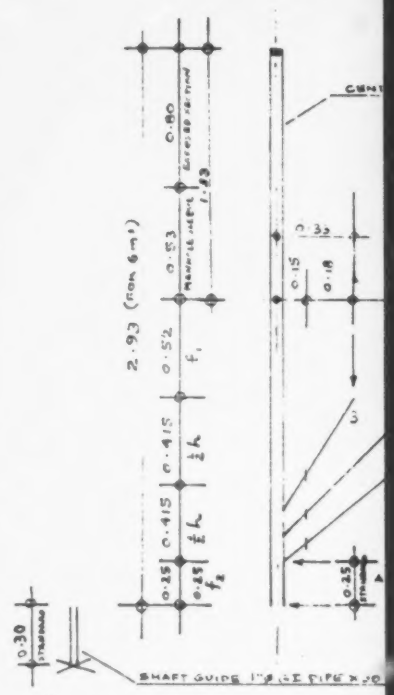
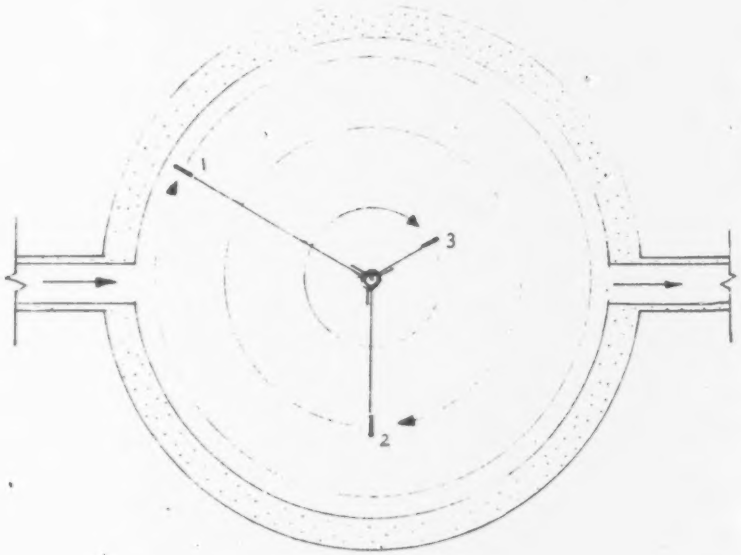
Appendix B (Cont.)

Design/Plan of a

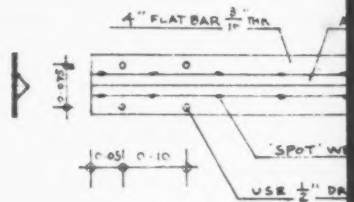








STIRRER BLADE :



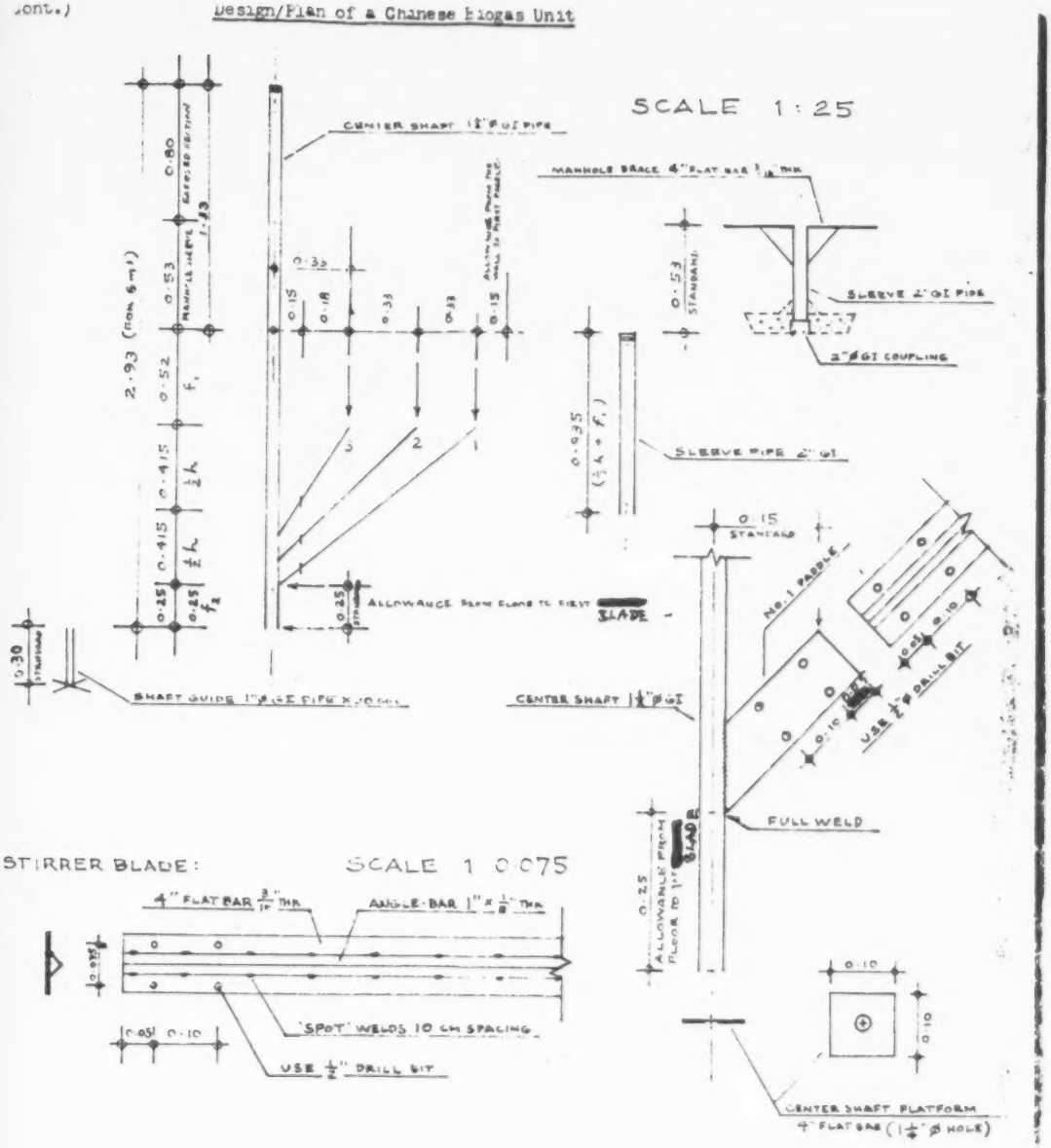
-ALL MEASUREMENTS IN ME

CHINESE BIO

DETAIL OF STIRRER

"CENTER-SHAFT ; STIRRER BL
MAN-HOLE BRACE ; CENTER SH

(cont.) Design/Plan of a Chinese Biogas Unit


SCALE 1:25
CENTER SHAFT 1½" Ø GI PIPE
MANHOLE BRACE 4" FLAT BAR ⅜" THK
SLEEVE 2" GI PIPE
2" Ø GI COUPLING
SLEEVE PIPE 2" GI
ALLOWANCE FROM FLOOR TO FIRST BLADE
SHAFT GUIDE 1" Ø GI PIPE
CENTER SHAFT 1½" Ø GI
NO. 1 PADDLE
USE ½" Ø DRILL BIT
FULL WELD
CENTER SHAFT PLATFORM
4" FLAT BAR (1¼" Ø HOLE)
STIRRER BLADE: SCALE 1:0.075
4" FLAT BAR ⅜" THK
ANGLE-BAR 1" x ⅛" THK
"SPOT" WELDS 10 cm SPACING
USE ½" DRILL BIT

-ALL MEASUREMENTS IN METERS (UNLESS OTHERWISE INDICATED) !!!!

CHINESE BIOGAS DIGESTER

DETAIL OF STIRRER/MIXER ASSEMBLY

"CENTER-SHAFT; STIRRER BLADES; SHAFT GUIDE; SLEEVE PIPE; MAN-HOLE BRACE; CENTER SHAFT PLATFORM"

DRAWN/DESIGN BY CHARLES H. NAKAGAWA
VISTA (CRS) / PHILIPPINES ... PHILIPPINE RURAL RECONSTRUCTION MOVEMENT

4 / 4

JULY 1981

Appendix C

ECONOMIC ANALYSIS/FEASIBILITY STUDY FOR
A FAMILY-SIZE CHINESE BIOGAS UNIT

1. Assumptions/Pre-Requisites

1) The family biogas unit has of a volume of 4.66 cubic meters. It requires roughly 45 liters of manure-water mixture (1:1 ratio) per day.

2) The gas produced will be used mainly for cooking and emergency lighting purposes.

3) Raw materials and water are available; this means 6-8 fattener pigs will be maintained at any point in time and approximately 45 liters of water available.

4) The biogas unit will be maintained and operated by the family. (Family-size biogas digester is small enough that the family does not need to employ a biogas operator/maintenance man for the assured normal daily gas production sufficient for the family's needs).

5) The whole unit costs approximately ₱2282 (consisting of ₱1,582 for materials and ₱700 for labor). (Prices are as of March 1981 in Manila.)

6) The life of the unit is more than 20 years. The study is based on cooking fuel (LPG) only.

7) LPG consumption for a family of six is ₱65 (price of one 40-kg. tank) for 25 days. This means an average daily gas consumption of ₱2.60. Furthermore, the price of LPG is not likely to decline.

8) Other major benefits of Biogas production, i.e., waste management, biofertilizer retrival, etc. are not computed in the calculations, because of its difficulty to make actual economic values, but should not be overlooked - "intangible benefits"

2. Cost And Return Analysis

The cost of the unit, which is ₱2,282, is spread over a 20-year period, the estimated service life of the unit. (However, in actuality the unit may last much larger.) In short, this is equivalent to ₱114.10 per year for the service of the unit. There are no other major costs involved in operating the project. Labor used in day-to-day operation is supplied by the family and is not computed. Hence, the net return of the project is considered as labor income.

Appendix C (Cont.)

The income from the project is reckoned from the saving on LPG only. It is assumed that a family of 6 persons consume on the average one tank of LPG costing ₱65 every 25 days, or ₱2.60 per day. In one year the cost of cooking LPG gas will cost ₱949.00. (Or, in 20 years the expense for LPG gas will be ₱18,980.00.)

Thus the estimated return per year to be derived from putting up a biogas unit is:

Annual Gross income (cost of gas)	-	₱ 949.00
Annual expense (cost of unit)	-	114.10
Annual net savings		₱ 834.90

Of a net saving of: ₱69.57/month, or ₱2.31/day.

It should be noted that the benefits derived from the fertilizers produced and the sanitation aspects are not included in the computation.

3. Payback Period

This is the time it takes to recover the initial investment out of the income expected as result from the investment. Payback period is computed as follows:

$$P = \frac{C}{E},$$

whereas; P = Payback period (in years),

C = Amount of investment,

E = Cost savings

Thus:

$$\text{Payback Period (in years)} = \frac{₱2282.00}{834.90}$$

$$= 2.7 \text{ years.}$$

Appendix D

ESTIMATED BILL OF MATERIALS FOR DIFFERENT DIGESTER VOLUMES

Item	Unit	Total Digester Volume				
		4 m^3	6 m^3	8 m^3	10 m^3	15 m^3
Phase I. (Basic Construction) Materials:						
Cement	40 kgm. bags	17	25	35	45	55
Sahara (for water proofing, optional)	Bags	10	15	35	35	45
Concrete hollowblocks:						
- 4" x 8" x 16"	pcs.	120	150	75	100	100
- 6" x 8" x 16"	pcs.	-	-	100	125	150
Round concrete pipes, 8" dia. x 36"	pcs.	3	3	3	3	3
Reinforcement bars, 3/8" dia. x 20', deformed	pcs.	20	30	50	60	70
Wax/paraffin	kgms.	7	10	10	15	15
Gravel and sand (mixed)	m^3	3.5	5	7	9	11
G.I. wire (#16)	kgms.	3	3	4	5	5

Appendix D (Cont.)

Item	Unit	Total Digester Volume				
		4 m^3	6 m^3	8 m^3	10 m^3	15 m^3
Lumber:						
- 2" x 2" x 10'	pcs.	5	7	9	11	13
- 2" x 1" x 10'	pcs.	4	6	8	10	12
Plywood or Fiberboard, 1/8" thk 4' x 8' (Lawanit)	pcs.	3	3	4	5	6
Nails:						
- 2½"	kgms.	2	2	2½	3	3
- 1"	kgms.	1/2	1	1½	2	2
Phase II (Finishing and Accessories) Materials:						
Plastic brush	kgms.	1	1	1	1	1
Paint brush	pieces	2	2	2	2	2
G.I. pipe:						
- 1" dia. x 2'	pcs.	1	1	1	1	1
- 1/2" dia. x 20'	pcs.	2	2	2	2	2
G.I. elbow:						
- 1" dia.	pcs.	1	1	1	1	1
- 1/2" dia. (straight)	pcs.	1	1	1	1	1
- 1/4" dia. (straight)	pcs.	1	1	1	1	1

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Appendix D (Cont.)

Item	Unit	Total Digester Volume				
		4 m^3	6 m^3	8 m^3	10 m^3	15 m^3
G.I. reducer:						
- 1" to 1/2" dia.	pcs.	1	1	1	1	1
- 1/2" to 1/4" dia.	pcs.	1	1	1	1	1
G.I. nipple, 1/4" dia. x 4"	pcs.	6	6	6	6	6
G.I. Tee	pcs.	2	2	2	2	2
Sprayer valve, 1/4" dia.	pcs.	2	2	2	2	2
Rubber hose with ply:						
- 3/4" dia.	meters	1/2	1/3	1/3	1/3	1/3
- 1/2" dia.	meters	10	10	10	10	10
Clear plastic hose, 1/2" dia.	meters	3	3	3	3	3
Corrugated G.I. sheet (New or used)	sheets	3	3	3	3	3

Appendix E

DIGESTER VOLUME AND QUANTITY OF DAILY SLURRY CHARGE
(Based on 40-Days Retention Time a/)

Total Digester Volume ($V_1 + V_2 + V_3 = V_t$) m^3	Digester Slurry Volume ($V_2 + V_3 = V_s$) m^3	Slurry Charge per day (Mixing Pit Volume)		Manure-Water Ratio Charge (Liters/kilograms)			
		m^3 b/	Liters/ kgms. c/	1:1 Ratio		1:2 Ratio	
				Manure	Water	Manure	Water
4.66	3.63	0.09	90	45.0	45.0	30	60
6.14	4.68	0.117	117	58.5	58.5	39	78
8.66	6.63	0.166	166	83.0	83.0	55	110
10.27	8.12	0.202	202	101.0	101.0	67	134
15.0	11.34	0.28	280	140.0	14.0	93	186

a/ This is Hydraulic Retention Time (HRT).

b/ Arrived at by dividing Digester Slurry Volume (V_s) by 40-days (Retention Time)

c/ Conversion Rate: $1m^3$ = 1,000 liters/kilograms of water.

Appendix F

ESTIMATED DAILY QUANTITY OF MANURE AND URINE AVAILABLE WITH RESPECT TO NUMBER AND WEIGHT OF PIGS RAISED a/ b/ c/

No. of Pigs	Manure Available (in kilograms)		
	Average market weight of 40 kgms./pig	Average market weight of 70 kgms./pig	Average market weight of 100 kgms./pig
1	2.0	3.5	5.0
2	4.0	7.0	10.0
3	6.0	10.5	15.0
4	8.0	14.0	20.0
5	10.0	17.5	25.0
6	12.0	21.0	30.0
7	14.0	24.5	35.0
8	16.0	28.0	40.0
9	18.0	31.5	45.0
10	20.0	35.0	50.0

a/ Estimated at 1 kilogram of manure and urine available for every 10 kilograms of liveweight, or a ratio of 1:10.

b/ Note: Above data are to be used as a guide. The best way is to check and measure the actual amount of wastes for 3 consecutive days and take the average. Quantity of manure may vary according to (a) size/age of animal; (b) feeds of animal; (c) degree of confinement; (d) urine collected, and (e) "wash"water included.

c/ Some other data: 1 cow or carabao gives 10-15 kgms. per day; 1 chicken; 0.09 per day.

Appendix G

ESTIMATED GAS PRODUCTION RATE
(Based on 0.4 - 0.6 m^3 of gas per 1 m^3 Slurry Volume Per Day)

Digester Volume (V_t)	Slurry Volume (V_s)	Gas Production/Day	
		Minimum a/	Maximum b/
m^3	m^3	m^3/day	m^3/day
4.66	3.63	1.45	2.17
6.14	4.68	1.87	2.80
8.66	6.63	2.65	3.97
10.27	8.12	3.25	4.87
15.0	11.34	4.50	6.80

a/ Slurry Volume (V_s) multiplied by 0.4 m^3.

b/ Slurry Volume (V_s) multiplied by 0.6 m^3.

Appendix H

MASONRY AS APPLIED TO BIOGAS CONSTRUCTION

Concrete is a versatile and relatively cheap building material. Most people are familiar working with concrete, either by observing its procedures or helping in building a simple structure. The method seems to be easy that everyone thinks that people who have constructed a concrete house or structure (that does not require strict specifications of being water-proof (and gas proof), can also build a concrete biogas unit. A word of caution: one crack and all the biogas leaks and renders the owner with the difficulty of repair that may also be costly and time consuming.

This material is an attempt to present certain basic facts about concrete work as particularly applied to building a successful biogas digester. These are simple facts which are often overlooked in common small-scale concrete work and may likely make a difference in the eventual overall performance of a biogas unit.

To prepare a durable concrete structure the builder should observe the following facts:

No. 1: 1) Select, prepare, and store the ingredients properly;

2) Use precise proportions of ingredients suitable for the job; and

3) Mix the ingredients properly with each other prior to adding the correct amount of water.

No. 2: 1) Select and use clean aggregates (free from soil, grass and other impurities);

2) Mix sand, gravel and cement thoroughly before adding water; and

3) Use the right amount of water (See No. 9).

No. 3: Concrete works well, provided it is compacted to eliminate "air pockets". (Note: 5% air voids in concrete reduces strength of concrete by 50%.)

No. 4: Concrete cannot be stronger than the aggregates used. Therefore, use mortar of the same strength as the aggregates.

No. 5: Sloppy concrete methods result in weak concrete structures.

Appendix H (Cont.)

No. 6: Concrete is porous, that is, it absorbs water through the minute voids in the concrete.

No. 7: Concrete is sensitive to extreme acid or alkaline conditions. (The slurry in the digester is generally acidic due to the presence of ammonia and hydrogen sulfide, but is not of the extreme condition.)

No. 8: There should never be more than 3 parts sand for every one part of cement in mixing concrete.

No. 9: Use a little water as possible in the mixture. Too much water weakens concrete and makes it less watertight.

No. 10: 1) The length of time spent for curing concrete is directly related to the strength of concrete. Concrete cured for 14 days is approximately twice as strong as concrete cured for 3 days.

2) Cover newly poured concrete with a wet material for at least 7 days. Prolonging the curing process strengthens and improves the water tightness of concrete.

No. 11: Onced mixed, concrete should be used within one hour after mixing.

No. 12: Cleanliness of anything that has to do with concrete work means strength, watertightness and gastightness of the resulting concrete. Thus:

1) Clean aggregates (gravel and sand);

2) Clean tools (shovel, measuring unit, mixing platform, trowel, buckets, etc.)

3) Clean cement;

4) Clean mixing area;

5) Clean surface;

6) Clean construction joints/connections;

7) Clean molds/forms;

8) Clean reinforcement bars;

9) Clean mixture.

Appendix H (Cont.)

Basic Elements in Concrete Work

1. Cement

Cement is a construction adhesive, essentially powdered, calcined rock and clayey material that forms a paste with water and "set" as a solid mass. The commercially available, commonly known as Portland Cement comes from the mill and packed at approximately 94 lbs. or 42.6 kg. packages.

Note: DO NOT BUY CEMENT UNTIL JUST BEFORE YOU ARE GOING TO USE IT. Under average conditions it may start to harden and deteriorate in 7-14 days. STORE IN A COOL, shaded and dry place, off the ground, and stack bags tightly. Once moisture reaches the cement, chemical reaction begins. Good quality cement is smooth and "flour-like". If it has hardened due to wetness to such an extent that the lumps could not be crumbled by hand, the cement should be rejected since its cementing value has already been destroyed.

2. Concrete

The concrete is made up of three ingredients: cement, aggregates (sand and gravel), and water. Careful mixing and correct proportions of the ingredients is the key in obtaining the desired results. On the job, make it a practice to mix, pour and finish all concrete work once the mixture is mixed and watered.

3. Aggregates

These are the hard materials such as sand, gravel and stone that are mixed with cement and water to make concrete. Aggregates should be clean and free from impurities. It should be always kept in mind that "the concrete cannot be harder than the aggregates being used". Therefore if cinders, coral, or broken soft bricks are to be used, the concrete will likewise be as strong or hard as the aggregates.

Aggregates are of two kinds: fine and course.

Fine aggregates are those particles that will pass through 1/4-inch screen mesh. This is possibly the most important ingredient in the concrete mix since it provides the "plasticity" of the mix making the mixture easy to work with. Ideally there should be no more than 3 parts sand for every one part cement. Too little sand may result in shrinkage or cracks when the concrete dries. Too much sand will produce a harsh mortar that will be difficult to work with and the overall structure may be weak. Never use sand from the ocean; the grains are too uniform in size and will not make good concrete. Any other sand source is good, but is crucial that it be clean.

Appendix H (Cont.)

Course aggregates, on the other hand, consist of gravel, stones, crushed rocks, etc. They will not pass through a 1/4-inch screen mesh and are usually less than $2\frac{1}{2}$ inches in diameter. Course aggregates add strength to concrete because they increase the range of grain sizes in the mixture. Generally they are the easiest ingredient to find and prepare locally. Aggregates must be coarse, hard and free from impurities such as organic matter, leaves, etc. As a rule of thumb, the size of the aggregate to be used should not be more than 1/2 the thickness of the concrete.

To determine the loam or soil impurities of aggregates, this simple test may be used.

1) Fill a one-liter bottle with sand up to 4 inches from the bottom and then fill it almost full of clean water.

2) Shake thoroughly and allow to settle overnight.

3) The loam and other fine materials will settle on top of the sand. If the layer is more than 1/8 inch thick, the sand should be washed, or another source of sand should be obtained.

4. Water

Water causes a chemical reaction in the cement, transforming it into an adhesive paste and hardening the concrete. Clean, pure water must be used for good quality concrete. Tap or spring water, or generally speaking, water fit for drinking is suitable for mixing concrete. Sea water and water high in alkali, acid or impurity contents should not be used.

It is a fact that for mixing concrete only a fraction of water in the mixture is used up in the chemical reaction that hardens the concrete. The remaining water escapes by evaporation, leaving minute voids that weaken the concrete. In theory, the mix should contain one part water (by weight) for every four parts cement. In this case, all the water would be absorbed in the hardening process and none left to evaporate. In practice, however, such a mix would be too stiff to use. Since in most cases the moisture content of the aggregates varies, it is impossible to state the exact amount of water to be used. To be safe, add just enough water to make the mix workable. And USE AS LITTLE WATER AS POSSIBLE.

The question of water is strongly emphasized since it is not uncommon to see many people who like to "drown" the mixture as it is much easier for them to prepare and work with the people who like to the mixture. This will lead to a much lower quality concrete. The best thing to do is to watch them carefully yourself. Supervise the addition of water to the mix.

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5. Mixing the Ingredients

Different uses and the desired hardness of concrete require different mixing proportions:

Uses	Proportion by volume of: Cement	Sand	Gravel
For structural members such as posts, beams, walls, etc.	1	2	4
For extra strength (rich mixture)	1	1½	3
For floors, walkways (medium mixture)	1	2½	5
For large massive structures like footing, etc. (lean mixture)	1	3	6

The mixing of the ingredients should be done in the following sequence or steps:

1) Spread the correct amount of sand on the mixing area with a shovel.

2) Dump the required amount of cement on the sand, and mix until the color of the pile is uniform; no streaks of color.

3) Add the required amount of gravel and mix it with the cement/sand mixture until the gravel is thoroughly distributed and coated. Again there should be no streaks of color, or "clumps" in the mixture. Note: Thorough mixing is essential for good concrete.

4) Hollow out a hole in the center of the mix. Add water slowly, pushing the ingredients toward the center while turning them over with a shovel. A good test for the correct amount of water is to walk on the mixture. If you sink to your ankles or higher, there is too much water; if you sink about 5-6 centimeters, you have the right mixture. THIS IS IMPORTANT AND VERY CRITICAL, OTHERWISE YOUR CONCRETE WILL NOT BE STRONG, AS WELL AS WATERPROOF AND GASPROOF. Too much or too little water renders the mixture uneven. Too much water causes a cement/water mixture to rise to the surface, weakening the mixture below, plus the minute voids in the concrete that the extra water will leave in the process of curing as mentioned earlier. Too little water leaves air spaces in

Appendix H (Cont.)

the mixture and does not give sufficient water for chemical reaction.

Once the mix is prepared, the mixture should be poured within one hour after mixing. Once in place, the concrete should be worked in well in place. A rod or spading tool may be used to break the air pockets. The planned pouring job for the day must be continuous and completed in one "pouring". If for the unlikely event that pouring has to be resumed the following day, roughen the edge of the previously poured section and paint it with a "pure" cement-water paste before continuing the fresh concrete pouring.

6. Curing

Curing is the hardening process of concrete. The quality of concrete - - its strength, as well as its watertightness and gastightness - - largely depends on proper curing, all other requirements being favorably met. Although usually not followed strictly in other concrete work it should NEVER be neglected in the case of biogas digester construction. The dome portion must especially be of high quality.

The dynamics of the concrete drying process is such that the initial evaporation within a concrete occurs on the outer layer, but the interior is still saturated with water. Thus, the concrete may appear dry or "cured" a few days after pouring, but it actually is not.

Proper curing involves keeping the concrete wet for sometime after it is laid. The newly poured concrete should be covered with a clean, water-retaining material, like burlap, cloth or sand and kept damp for at least several days during the curing process.

Prolonging the curing process increases the quality of concrete. As mentioned earlier: concrete cured for 14 days is approximately twice as strong as one cured for 3 days. More specifically: concrete kept damp for the first 10 days is 72 percent stronger than if left to cure in dry air for 3 days. Keeping it damp for 21 days increases its strength by 124 percent; 4 months dampness, by 207 percent. While the flooring is being cured, it should be kept clean and protected from soil impurities and excessive loads.

Important Considerations In Preparing Concrete

The following should be considered for proper masonry work:

1. Mixing Area

Concrete should be mixed on a flat, clean surface which will not

Appendix H (Cont.)

absorb water. A standard mixing platform is made from wood about 2 meters by 3 meters. Another is a cement-sand platform. (To build a cement-sand platform, mix 1 part cement and 6 parts sand on that ground close to the work site. Add water and spread the mixture in a circle before using the platform.)

Or usually the site for the biogas tank will be close to the pig pen, so it is convenient to use the pig pen floor as the mixing platform. Keep away foreign materials - - soil, grass, etc. - - from the mixing area.

2. Measuring Unit

The proportions of the any ingredient of concrete - - namely cement, sand and gravel - - are measured by volume. Decide on a standard measuring unit, such as a box that holds 1 bag of cement (or cubic foot). The box should have handles on both sides for easy lifting by two people. It is advisable not to change measuring units during construction. Measuring units should be cleaned if it had been used for hauling soil or other debris.

3. Molds or Forms

Molds are necessary to hold the concrete to the desired place, and shape until it is cured. Being semi-fluid, concrete takes shape of anything into which it is poured.

The length of time necessary to keep the forms in place depends on the nature of the structure. For small construction work where the concrete bears no external weight, the forms may be removed as soon as the concrete will bear its own weight. Usually this is between 12 and 48 hours after pouring the concrete.

The forms must be relatively watertight, rigid and strong enough to sustain the weight of the concrete. They should also be simple and economical and if to be used again, designed so that they may be easily removed and re-erected without damage to themselves (or to the concrete). Wood, plywood or fiber board forms are versatile and cheapest, but for repetitive use, G.I. sheets may be advantageous as they are not easily damaged by water.

Reinforced Concrete

Reinforcing concrete enables it to attain greater strength with reduced thickness. Concrete foundations, walls, floors and columns can increase their strength by 2-5 times when reinforced.

Appendix H (Cont.)

Reinforced concrete combines two materials with different or opposite but mutually reinforcing strength characteristics needed by structures. Concrete resists compression or downward pressure; it does not bend but it breaks or cracks instead. Iron rods (or usually deformed bars) resist tensile or breaking pressure; they bend and buckle under compression.

The preparation and handling of reinforced concrete is the same as that of plain concrete, except that an iron rod, or a series of rods, are fastened inside the "form" or "mold" before the concrete is poured in.

Reinforced concrete is the strongest, long lasting material of all (especially in wet and stormy climates and earthquake-prone areas), but is expensive because of iron rods, time and labor.

The reinforcement rods must be free from dirt, oil or rust, to insure adherence of cement to them. If necessary, clean the iron rods of forein particles with the use of a steel brush.

The iron rods must be completely surrounded by concrete, at least 2.5-5 centimeters. Any exposed rods will not be maximizing the use of such rods.

When using hollowblocks, there should be one horizontal iron rod for every two coarses of hollowblocks. This is roughly 40 centimeter reinforcement spacing. There is also one vertical iron rod for every two layers of hollowblocks, meaning 80 cm spacing between hollowblocks.

There are certain proportions between "size of rods" and "thickness of concrete", but it is not always true that "the thicker the concrete, the stronger it is" (this is reinforced-concrete fiction No. 1). In fact, by increasing the thickness of the concrete may render the iron rods useless because they can no longer hold the tensile and shearing stresses exerted by the concrete mass.

In determining the thickness of circular or domed structures, the RULE OF THUMB is: Thickness of sphere (or by the circular form) is sufficient when it equals one-tenth of the inner radius of the circle. Hence:

for 4.66 m^3 biogas digester

- Radius (R_1) = 1.5 m.
- Thickness of dome = $\frac{1.5 \text{ m}}{10}$ = 0.1 m.

and

for 15 m^3 biodigester

- Radius (R_1) = 2.5 m
- Thickness of dome = $\frac{2.5 \text{ m.}}{10}$ = 0.2 m.

Appendix H (Cont.)

Watertight And Gastight Concrete: A Further Emphasis

The crucial need for having watertight and gastight concrete biogas digesters and the factors that will make it so have already been discussed. They are repeated here only to emphasize their importance in obtaining the desired results. It is very important to realize that the success of a biogas digester is dependent on the ability of the tank to hold water and gas at high pressure (sometimes up to 2 meters water column pressure).

In review, the essential requirements for concrete impervious to water and gas are as follows:

1) Good quality of aggregates: clean, correct size and proportions;

2) Limited amount of water; clean and in correct amount;

3) Thorough mixing: a plastic, workable mixture;

4) Proper placing and pouring; no voids and air pockets in the concrete; and

5) Favorable curing conditions.

It must be emphasized that water-proofing a concrete is difficult, and that gas-proofing it is even more difficult. A concrete additive may be used to further insure that the concrete will be watertight/gastight together with the above-mentioned requirements. Commercially available "water-proofing" agents/compounds come in various trade names in the Philippines (e.g. "SAHARA", "Philidelphia", etc.). It is recommended that an additive be used. Follow directions provided on the package. To further achieve gastightness of the gas portion of the digester, very good results have been experienced by applying paraffin/wax for the interior surface of the dome. This is recommended highly for achieving the desired results.

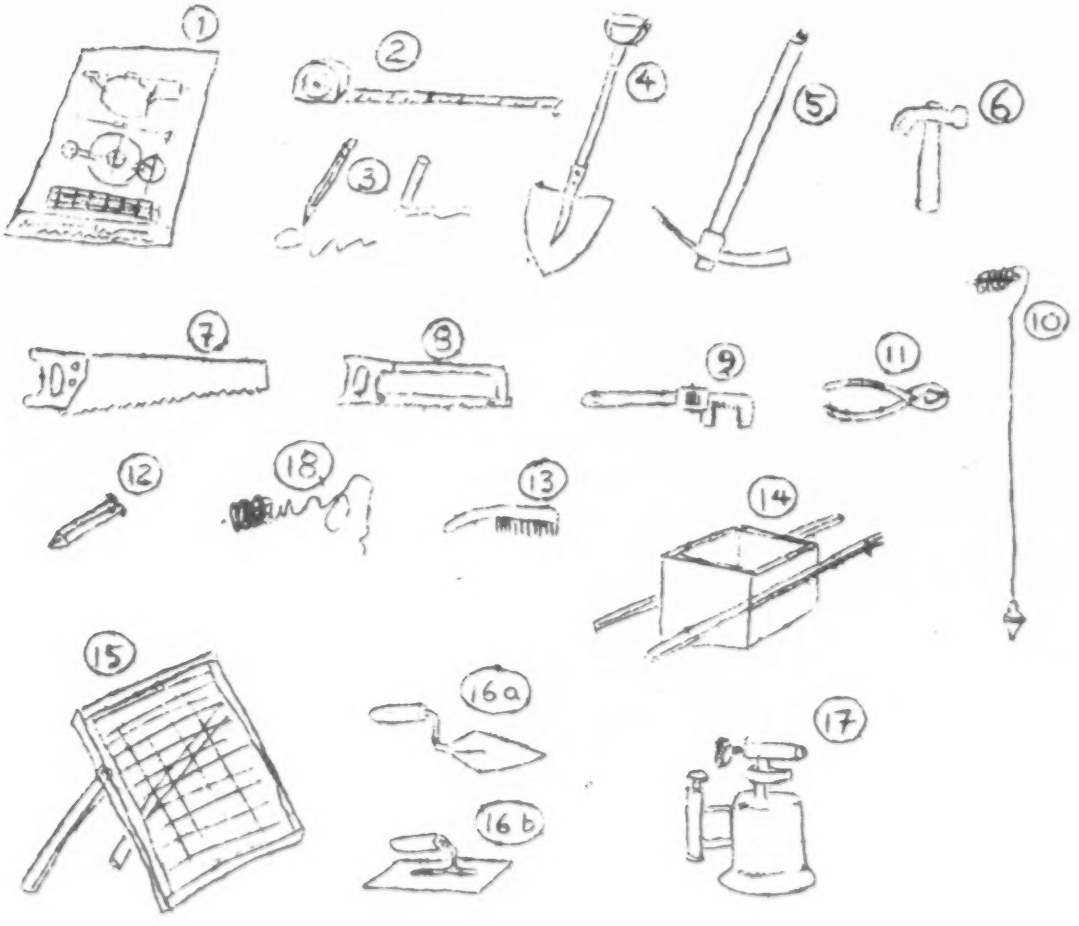
For practical purposes, the amount of mixing water should not exceed about <u>six-gallons</u> per bag of cement, and not more than <u>five gallons</u> if the sand is damp. The accumulation of undue water on the surface of the mixture should be avoided, and all whitish "scum" consisting of finer materials which may float and collect should be removed. Pouring of concrete should be continuous (or monolithic) especially the gas portion of the digester. Any interruptions in the pouring should be avoided; if for some reason it must be interrupted, proper construction joints and rough-finish (or "scratched") surfaces in which pouring is to resume should be adequately provided for.

Concrete should be kept wet for two weeks and longer when practicable. Keeping the concrete "damp" prolongs the curing process which is necessary for strengthening the concrete structure.

Appendix I

BASIC MANUAL TOOLS FOR BIOGAS CONSTRUCTION

1. Design/plan; 2. Tape measure; 3. Pencil or chalk; 4. Shovel; 5. Pick; 6. Hammer; 7. Saw; 8. Hacksaw; 9. Pipe wrench; 10. Plumb-bob; 11. Pliers; 12. Chisel (for concrete); 13. Steel brush; 14. Measuring box (1 cubic foot); 15. Sifter (G.I. screen); 16. Masonry trough (a. regular; b. plastering); 17. Blow-storch; 18. String (at least 3 meters).



Appendix J

USEFUL FORMULAS AND CONVERTIONS

Area of a Circle = πr^2

where: π = 3.1416 (constant)
r = radius of circle

Circumference of a Circle = $2 \pi r$

Volume of a Cylinder = $\pi r^2 h$ or $\frac{\pi}{4} d^2 h$

where: r = radius of cylinder
h = height of cylinder
d = diameter of cylinder

Volume of a Sphere Segment = $\pi h^2 (r - \frac{h}{3})$

where: h = height of arc
r = radius of sphere

Conversion factors:

Centimeters	x 0.3937	= Inches
	x 0.3281	= Feet
	x 0.01	= Inches
	x 10	= Millimeters

Cubic feet (Ft^3)

x 283.2	= Cubic centimeters (m^3)
x 1,728	= Cubic inches (In^3)
x 0.02832	= Cubic meters (m^3)
x 7.4	= Gallons
x 28.32	= Liters

Cubic meters (m^3)

x 1,000,000	= Cubic centimeters (cm^3)
x 35.31	= Cubic feet (Ft^3)
x 61,023	= Cubic inches (In^3)
x 264.2	= Gallons
x 1,000	= Liters

Gallons (Liquid)

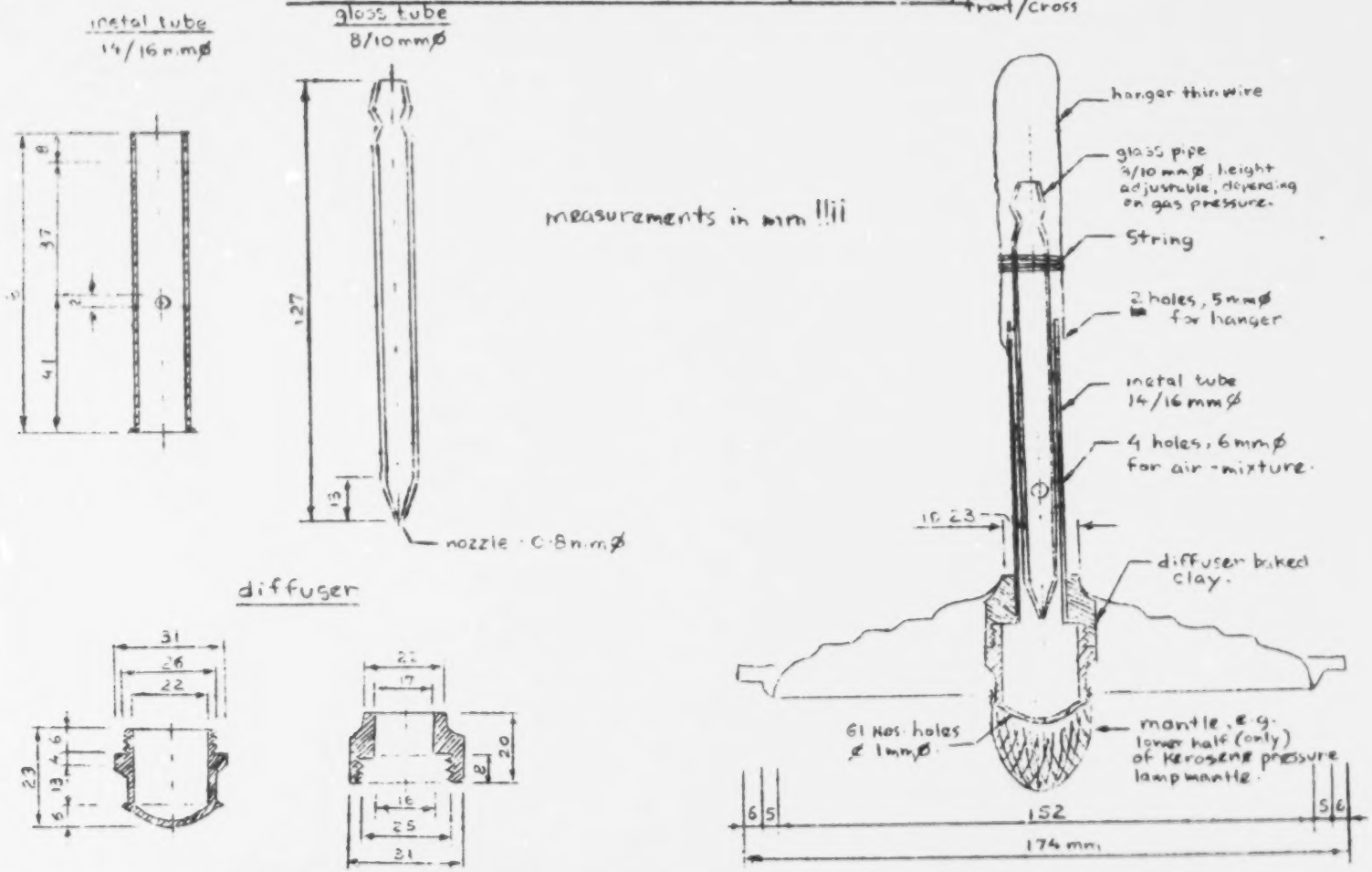
x 3,785	= Cubic centimeters (cm^3)
x 0.1337	= Cubic feet (Ft^3)
x 3.785	= Liters

Appendix J(Cont.)

Inches	x 2.54	=	Centimeters
	x 0.0833	=	Feet
	x 0.0254	=	Meters
	x 25.4	=	Millimeters
Meters	x 3.281	=	Feet
	x 39.37	=	Inches
	x 1.094	=	Yards
	x 100	=	Centimeters
Kilograms	x 1000	=	Grams
	x 2.205	=	Pounds
	x 0.001102	=	Tons
Liters	x 10^3	=	Cubic centimeters (cm^3)
	x 0.001	=	Cubic meters (m^3)
	x 0.0353	=	Cubic feet (Ft^3)
	x 61.02	=	Cubic inches (In^3)
	x 0.2642	=	Gallons
Others:	1 psi	=	70.3 centimeter column of water
		=	27.68 inch column of water
		=	51 millimeter column of mercury
		=	0.068 atmosphere

Appendix K

"DETAILS FOR CONSTRUCTION OF A BIOGAS LAMP (HANGING MODEL)" a/



a/ Source: FAQ Soils Bulletin, #41, "China: Azolla Propagation and Small-Scale Biogas Technology", FAO/UNDP, 1978.

Appendix L

BACKGROUND NOTES AND ACCOUNT OF BIOGAS PRODUCTION IN THE PEOPLE'S REPUBLIC OF CHINA

The People's Republic of China is a country famous for the age-old tradition of recycling organic wastes in agriculture. It is claimed that its farmers meet two-thirds of their fertilizer needs from organic sources. Wastes of all kinds are viewed as resources "out-of-place"

Experimentation and promotion of biogas technology in response to the search for better ways of utilizing wastes began in China in the late 1950's. All-out efforts were made to improve on the traditional methods of composting human, animal and plant wastes to produce high quality fertilizers. The breakthrough came in early 1970's when they were able to develop a simple watertight and airtight digester from locally available building materials (bricks, limestone, etc.) at a cost individual households could afford.

Along with producing fertilizers of high quality, other benefits were recognized in the process. Methane-gas was produced as fuel not only for cooking and lighting but with larger biogas units for internal combustion engines to supply farm power and rural electricity. Rural sanitation greatly improved by destruction of pathogens that causes common rural diseases. In the past, night soil was bucketed out to the paddy fields untreated, resulting in the spread of diseases like schistosomiasis, blood fluke, round worms and hookworms, now, digestion of night soil in a watertight and airtight digester prevents the breeding and spread of disease-carrying organisms, thereby reducing public health hazards. All this has brought about the realization that biological treatment of organic wastes in a biogas digester is the simplest, cheapest and most practical method known for sanitary handling of human and animal wastes. Thus, biogas technology has been able to solve not only waste management and rural sanitation problems, but also produce high quality fertilizers and fuel.

The experience in China is that a household digester can be built from locally available materials and labor for as little as $15 - $25 (¥112.50 - ¥187.50). It is estimated that 95% of all biogas digesters built are of family-size where the gas produced is primarily used for cooking and lighting and the effluent for fertilizer of the family's own fields.

It is a general impression that the major constraint to the spread of biogas technology to the rural areas of the Third World is the high initial capital cost of the digester. Thus, conclusions were made that "community" digesters should be recommended over "individual" digesters in order to reduce costs, but there are many problems associated with community digesters. If digesters could be made at low-cost, there is a need to reexamine the notion that individual household digesters are capital intensive. The Chinese have shown us their resourcefullness and the example of building a digester inexpensively by utilizing locally available

Appendix L (Cont.)

building materials and a different design concept. They make use of materials available in their own specific areas or regions. People along rivers use pebbles and stones; those in the plains use bricks, and those in the mountains may even carve their digesters out of sheer rock! They also make their own concrete, called, "triple-concrete" made out of a mixture of lime, clay and sand.

Biogas production technology is recognized as fairly sophisticated and complex. Construction is stressed to be meticulous so as to guarantee durability, watertightness and gastightness without having to be necessarily expensive in building materials. It also emphasizes that operation and maintenance of the biogas unit is equally important for satisfactory performance in producing gas and fertilizer and achieving sanitation.

A biogas manual, available in bookstores throughout China, points out that the technology is sophisticated and that special care must be taken in both construction and operation of the units. It advices people to try different techniques on a small-scale before attempting it on a lare-scale, and to test carefully for safety and airtightness. The manual also tries to give the reader an idea of what goes on "out-of-sight", underground in a working digester.

The success of in the promotion of biogas technology in China can be largely traced to their system of organization and program integration on the national level. Biogas production is for social reconstruction and rural transformation supported through national conferences, training of biogas technicians; manufacture of simple gas stoves and lamps, rubber or plastic piping materials, and simple pressure gauges; making available financial support; and providing research and development for designs and construction techniques.

The technology transfer process is likewise well organized. Before the start of a biogas project a brigade will send several members to another brigade as "apprentice" to learn all aspects of the technology. After having experienced in construction and maintenance there, these people return as "technicians" to begin a biogas program in their own brigade. They are responsible for the construction and operation of the biogas plants, for the training of other technicians, and for the supervision and assistance needed by individual families building their own digesters. The families receive instructions on how to release the gas, how and when to feed the digester, and how to maintain the proper liquid-solid balance within the digester.

The Chinese empty or clean their digesters twice a year (or "batch" type of operation) since their primary concern is to produce biofertilizer. And also, the use of grasses, rice straw, water weeds and crop residues, which commonly leads to "scum" problems necessitates periodic and shorter-interval cleaning of the digesters. Another limitation in China, of course, is lower climatic temperatures especially in the northern areas. This lowers gas production considerably during the cold winter months.

Appendix L (Cont.)

Some example of common combinations of raw materials used in China are:

1) 20% urine, 30% nightsoil, 50% water;

2) 10% night soil, 30% animal manure, 10% straw, 50% water;

3) 20% night soil, 30% pig manure, 50% water;

4) 10% night soil, 10% animal manure, 30% grass, 50% water.

In popularizing the technology, the Chinese claim the following advantages of biogas:

1) Biogas production protects forest and timber - - saves firewood which is in short supply in most areas of the country.

2) Manure from biogas digestion is richer in nitrogen content and contains more quantity of nutrients than that from conventional composting. Through research findings they claim that:

   a) ammonia up by 120%;

   b) quick-acting phosphorus up by 150%

   c) wheat yield increases by 17% over that treated ordinary compost.

3) Manure from biogas plant is free from offensive odors, compared to manure from compost pits/heaps. Parasites are killed during digestion process, thereby resulting in a healthier environment.

4) Biogas conserves local fuel - - firewood, coal, kerosene. Additionally, the process produces excellent fertilizer from human, animal and plant wastes which otherwise would present health hazards or merely burned away.

5) Biogas can substitute for petroleum to run internal combustion engines to supply electricity and other power needs in the rural areas.

6) Biogas provides clear, convenient fuel for household cooking and good light for reading. Rice straws which once were burned for fuel can now be used for animal bedding or feed.

7) Biogas saves time in cooking, thus reducing housekeeping chores for women.

8) Biogas production is complementary to piggery development.

Appendix L (Cont.)

As of 1972, China has seven million biogas units. How could China have achieved such record success while other countries were struggling with problems of technology dissemination. The answer may lie in at least two important reasons. One is the Chinese national spirit of self-reliance and determination to make the most of its available resources and ingenuity. The other reason is in the practical aspects of both the design breakthrough of the biogas digesters as well as of the application of technology itself.

The practical design attributes of Chinese digesters are:

1) Simplicity - - no moving parts in operation;

2) Use of locally available building materials;

3) low cost;

4) minimum metal materials and welding necessary;

5) requires a comparatively simple way of building/construction;

6) use of local skills and workmanship;

7) considerations given for local conditions;

The biogas technology attributes, on the other hand, focus on real felt needs:

1) conservation of natural resources;

2) utilization of abundant animal and agricultural wastes;

3) strongly directed toward polution control and environmental sanitation;

4) exploitation of a self-reliant based source of energy.

Appendix M

GLOSSARY

Aerobic decomposition - Decay of organic matter in the presence of oxygen.

Anaerobic decomposition - Decay of organic matter in the absence of oxygen.

Anaerobic bacteria - Bacteria which do not used oxygen to live.

Batch-Load Operated Digester - A method of filling a digester wherein the digester is filled all at once, sealed and emptied when the materials have stopped producing gas. The digester is then filled again.

Biogas - A combination of gases produced by anaerobic decomposition.

"Charge" - A mixture of manure and water to be fed into the digester; also an act of filling the digester with manure-water mixture.

Continuous-Loading Operated Digester - A method of filling a digester a little at a time or regularly so that gas and fertilizer are produced continuously.

Digester - The part of a biogas unit where wastes undergo the digestion process.

Digestion - The breakdown of organic materials by biological action. Or the process by which complex organic compounds are broken down into simpler organic molecules; in biogas production, the anaerobic process by which bacteria accomplish this breakdown of organic matter.

Effluent - The liquid and/or solid that comes out of the digester, such as slurry, sludge or scum.

Manometer - A low-cost devise for measuring gas pressure, such as a water-column gas pressure gauge.

Night-soil - Human feces.

Parasite - An organism which lives on a different larger animal, such as worms living in the stomach of an animal.

Pathogen - An organism which causes disease in both animals and humans.

Appendix M (Cont.)

pH - A measure of acidity and alkalinity of a substance or a solution. For instance, pH 7 is neutral; pH lower than 7 is acidic; pH greater than 7 is alkaline.

Retention time - The time the slurry spends in the digester.

Scum - Light materials that rise to the surface of the slurry in the digester. The accumulation and removal of scum is one of the serious problems with biogas digesters.

Sludge - The materials consisting mostly of solid particles that settle at the bottom of the digester.

Slurry - The mixture of manure and water to be fed into the digester.

Toxins - Substances that can kill or "poison" bacteria, like pesticides, disenfectants, etc.

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